



ELSEVIER

Contents lists available at ScienceDirect

Space Policy

journal homepage: www.elsevier.com

Preserving Mars Today Using Baseline Ecologies

Daniel Capper *

School of the Humanities, University of Southern Mississippi, 118 College Drive, #5037, Hattiesburg, MS 39406, USA

ARTICLE INFO

Keywords:

Aldo Leopold
Base-datum of normality
Environmental preservation
Mars
Planetary protection
Valles marineris

ABSTRACT

Current calls to protect the Martian environment with “Planetary Parks” maintain environmental merit. However, they lack a sufficiently urgent timeframe for initiating protection and a robust scientific method for the establishment of noteworthy Martian natural landmarks as natural reserves. In response, if we return to the seminal environmental preservation teachings of Aldo Leopold and John Muir, we encounter the importance of grounding Martian preservation efforts on the fundamental environmental science method of a base-datum of normality, or baseline ecology. This method establishes natural reserves that feature both minimal human interference and known origination dates, thereby providing longitudinal environmental control samples for scientific use. Applied before humans appear on Mars, preserved baseline ecologies thereby aid our scientific understanding of human environmental impacts, both now and well into the future, while they enhance a variety of other outcomes in terms of Martian protection. However, the baseline ecology method requires that, through international agreements, we establish these reserves as quickly as possible and certainly before humans arrive on the planet.

1. Introduction

Along with various private companies, NASA has announced plans to land humans on Mars by around the year 2040 [1]. When humans, who consist of dense biotic populations that rely on other biological communities, dwell on Mars, the threat of the forward contamination of the planet with Earth biological entities appears inevitable [2]. The results of such biotic insertions will be unpredictable, from the death of Earth microbes on the harsh Martian landscape to the surprising but troublesome flourishing of tiny stowaways who, perhaps underground, find a way to adapt to a new home. Indeed, the astrobiologist David A. Weintraub [3] recently issued a strong warning that, despite cleanrooms and international Committee for Space Research (COSPAR) regulations, we already technically have contaminated Mars and persist in danger of compromising Mars for scientific study through unintentional biotic dispersal, which can create false-positive experimental results.

Adding to the threat of unwanted biological export, the ethical debate regarding the possibility of terraforming Mars to make it more hospitable to Earth creatures remains unresolved, despite the peril of manipulating the ecology of another planet before we really under-

stand the ecological functioning of our own. While undoubtedly we may learn more about Earth processes by changing those of Mars, nonetheless, given current knowledge, James S. J. Schwartz wisely writes, “Activities such as space mining and colonization cannot be undertaken prudently in ignorance of the chemistry, geology, climate, etc., of space environments” [4].

Given these conditions, what we find on the horizon is not just the scientific self-destruction through improper approaches that Weintraub fears but also the potential ethical diminution of humanity. In theory, we could problematize Mars for science yet genuinely find life another time on another world. But nothing ever will remove the failing grade from our species’ ethical report card arising from the environmental fouling of a planet.

In response to these scientific and ethical threats, in this article, I describe the protection of the most important natural landmarks of Mars with conservation and preservation reserves. First, I discuss a similar proposal of this ilk and find that protecting Mars requires greater alacrity and a more robust scientific method. I then offer a system for preserving Mars based on the foundational environmental scientific and preservationist strivings of Aldo Leopold and John Muir. Afterward, I describe, as an example of this preservation system, a proposed

* Fax: +1 601-266-4522.

Email address: Daniel.Capper@usm.edu (D. Capper)

Valles Marineris International Ecosphere Reserve so that I may emphasize that we should initiate the international governmental protection of Mars' environment immediately, exactly because no humans exist there yet, and in so doing perform better science right away. Finally, I delineate a space policy path for the adoption of this proposal.

2. Planetary Parks and preservation legislation

To provide Mars with some protection from the threats of biological contamination and certain types of terraforming, in a pair of articles, Charles Cockell and Gerda Horneck [5,6] usefully propose the establishment of a system of seven "Planetary Parks" on Mars. These authors argue that seven areas should be officially preserved for the intrinsic worth of their natural splendor, their utilitarian value for science, their historical value, our responsibility to the future, and possible future human recreation on the Red Planet. Areas suggested for protection include the North Pole, Olympus Mons, Syrtis Major, the southern ground ice region, Hellas Basin, Valles Marineris, and a historical park that includes Viking 1, Pathfinder, and the Sojourner rover. In these protected spots, no waste can be left, access must be on foot or via defined vehicle routes, no spacecraft can land, and everything coming near the reserve must be sterilized. Although contaminants blown by winds into these reserves cannot be prevented, the authors contend that specially protecting locations still minimizes their chances for contamination [5]. In addition, the authors request that this preservation occur soon, for this will advance our civilization, respond to Mars' intrinsic value, provide a legacy for the future, and prohibit unintentional destruction of unknown future benefits [6]. Given its responsible environmental contours, the insightful proposal of Cockell and Horneck [5,6] could inject an important dynamic element into planetary protection strategies.

Critiques can be leveled at this literature, although, including, I will argue here, insufficient urgency and an undeveloped scientific method for realizing preservation. The literature does not really counter the objection, "Why establish nature reserves on a planet without humans?," because, for just one example, perhaps citizens do not feel much like advancing their civilization right now, leaving the protection of Mars neglected. Yet exploring Mars demands that our environmental ethics and behavior keep pace with our technological prowess, and this requirement cannot be overlooked.

By reframing Cockell and Horneck's [5,6] claims regarding the future in terms of classic works within natural preservation policy, the preservation of Mars demands greater earnestness and clarity than their argument allows. Cockell and Horneck [5,6], as others have done, rely heavily on the text of the US Wilderness Act of 1964, one of the most important pieces of legislation regarding the preservation of uninhabited locations. Alternatively, by not relying on the politically contested text of the Act like Cockell and Horneck do and turning instead to its preservationist inspiration in the works of the foundational environmentalists Aldo Leopold and John Muir, we discover a most effective scientific method for practicing Martian preservation. As I will describe more fully, Leopold's originally scientific method of a base-datum of normality [7], or a baseline ecology, which remains understated within the Wilderness Act legislation, permits the enhanced preservation of Mars in terms of science, culture and history, future recreation, as well as respect for majestic natural features alike. Crucially, though, Leopold and Muir also teach us that we need to enact the intergovernmental environmental preservation of Mars, as I describe in Section 8, as soon as possible precisely because no humans are there now. We better get a sense of my contentions if we turn to the natural preservation perspectives of Aldo Leopold.

3. Leopold's baseline ecologies

Following John Muir and influenced by him, Aldo Leopold (1887–1948) [7], a giant as an academic scientist and lay ecologist, gathered themes in Muir's thought, as well as his own, to forward the beneficial notion of a "base datum of normality, a picture of how healthy land maintains itself". Leopold [7] noticed that the practice of science involves experimental controls, yet environmental science sometimes struggles with these because in many situations, ecology consists instead of a cacophony of uncontrollable, ever-changing variables. In response, Leopold [7] argued for the preservation of specific uninhabited locales that remain protected from nonscientific human intrusions and therefore supply science with historical freely developing ecological samples, or "most perfect norm" controls for comparison.

Leopold's original formulation of the base-datum of normality included his now-outdated notions of ecologies as organisms. This organismic thinking undergirded his famous "land ethic," for instance, in which he asserted that "a thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong when it tends otherwise" [8]. Nonetheless, the base-datum of normality method does not require this organismic presupposition and remains fruitful without it. Hence, in this article, I set aside the concept of land as organism and redefine Leopold's method with the concept of the baseline ecology, which consists of supplying ecological science with a relatively human-free ongoing historical control sample.

In Leopold's method, preserving an area from human influence creates a historical baseline ecology as a form of experimental control with a discreet, known origination date from which researchers can work. It is important to understand that this baseline ecology concept does not consist of forcing an area to remain as we found it or want it to be, for this will forestall the ecological succession, biotic and not, that we seek to understand. Instead, Leopold [7] argued, such reserves, left unmolested to develop as they will, eternally provide known temporal baseline ecological scientific data from the historical point of inception of the reserves. A hundred years in the future, for instance, understanding how an environment has changed over a century without undo human interference can provide enormous scientific value. Furthermore, as Swetnam et al. [9] state, baseline ecologies can "be used, along with current condition assessments, social and economic considerations, and other practical constraints, for the setting of achievable and sustainable [ecological] management goals."

On Mars, the baseline ecology strategy, if pursued before humans reach the planet in person, can supply invaluable longitudinal scientific perspectives regarding human effects on Martian ecologies as well as those ecologies in themselves by providing relatively human-free historical environmental control samples. Even if these environments are abiotic, such environments still remain dynamic and undergo their own forms of ecological succession, and there is much that we can learn from studying these ongoing processes. This tactic also may help us, unknowingly as of this writing, to preserve Martian life forms, which would benefit those beings, our science, and our consciences alike, should this event occur.

Wielding Leopold's baseline ecology method to argue politically for preservation, Benton MacKaye, one-time President of the Wilderness Society, helped to lead the successful environmentalist campaign to block the construction of the Echo Park Dam in 1955 [10]. Also, a Wilderness Society leader and impressed by Leopold's argument regarding scientific value, Howard Zahniser, a motive force behind the important U.S. Wilderness Act of 1964 that Cockell and Horneck cite [5,6], subtly integrated Leopold's baseline ecology concept into rhetoric for his public pleas for the Act [11]. Given Zahniser's ministrations, Leopoldian baseline ecologies thus vicariously speak to us through the Wilderness Act despite their relative invisibility in the intensely politi-

cally contested verbiage of the actual bill. Thus, the Act offers some useful reasons for preservation and a legal definition of “wilderness” [12], but looking behind the bill to its inspiration from Leopold provides a solid scientific method for pursuing this preservation.

However, despite its success in motivating environmental legislation, since the time of the adoption of the Wilderness Act, Leopold's baseline ecology method has witnessed only limited uses by environmental scientists, in part given the complications that emerge from proximate Earthly humans. The baseline ecology method works best when initiated in places mostly untouched by humans, but no location on our planet genuinely matches that description any more. Today's Mars, though, lacks any members of *Homo sapiens* and hence avoids this defect, allowing us to reinvigorate Leopold's environmental science method in the brilliant sunshine on Hellas Planitia.

By following the baseline ecology method to protect places of intrinsic natural value on Mars before humans arrive, we thereby can practice improved science. Through the baseline ecology method, present and future scientists can more decisively understand how human presences change historical Martian environments as well as how those environments, even if abiotic, change themselves. With ecological helpfulness, we also answer the call of the environmental ethicist Holmes Rolston [13] to “set aside wild areas for what they are in themselves, areas which we try to manage as little as possible.”

Although arising from within scientific pursuits, Leopold's method of creating baseline ecologies as historical environmental controls additionally magnifies nonscientific reasons for preserving regions of Mars, and these reasons impact the need for timely preservation efforts. The American naturalist John Muir helps us to understand why with his approach to natural preservation.

4. Muir's conservation and preservation arguments

John Muir (1838–1914) provided the momentum behind the establishment of the National Park System of the United States in 1916. In this campaign, Muir made four arguments for the preservation of natural places, and Cockell and Horneck's [5,6] reasons for protecting Mars reflect similar themes. Muir began with respect for the places themselves in their own rights, observing their intrinsic value. It remained obvious to him that trees, rivers, mountains, and even tarantulas and rattlesnakes deserve respect and care because of their various unique roles in creation [14,15]. But, of course, the claim that talus slopes should be protected for their own sakes often moves the environmentalist more than the politician who legally creates reserves, so Muir continued. He also argued for natural preservation for cultural, educational, and historical reasons, as he gushed that Yellowstone National Park existed “for the benefit of the people” [14]. As we see with Leopold, Muir additionally sought natural preservation for the sake of science, with Muir's insisting that the bare stones of Yosemite represented “rocky pages” [14] of a science book. The politically winning argument, however, was that nonhuman nature should be reserved for human recreation, and this reason has shaped United States natural preservation legislation, including the Wilderness Act, since that time [12]. At the same time that he made these arguments, though, in some situations Muir also approved of land use in the form of logging, as long as the cutting was sustainable and limited to specific areas [14]. Hence, Muir provides plural reasons for preservation (stringent protection of nonhumans) mixed with some conservation (sustainable interactions with nonhumans). In this way, he illuminates the importance of considering protected Martian sites with multipurpose recreation, conservation, and preservation capacities, such as with the proposed Valles Marineris International Ecosphere Reserve, as a part of the argument for rapidly imposed protection.

5. Valles Marineris International Ecosphere Reserve

Although Leopold designed the idea of a baseline ecology for scientific purposes, we can appreciate that his idea actually energizes every reason for natural preservation given by Muir, not just the one concerned with science, especially if we apply them to Martian realities. For instance, we can create multipurpose reserves that include Leopoldian goals within the seven sites helpfully identified by Cockell and Horneck [5,6]: the North Pole, Olympus Mons, Syrtis Major, the southern ground ice region, Hellas Basin, Valles Marineris, and a Viking 1-Pathfinder-Sojourner rover historical reserve. Choosing these imposing sites for our baseline ecologies recognizes their intrinsic value as sublime spots of “supreme grandeur and beauty,” as Muir stated [14], so that in preserving them, we extend “our respect for the landscapes and features of the planet,” as Cockell requested [16]. Moreover, in preserving them, we may recognize and appreciate the intrinsic, utilitarian, aesthetic, and scientific value of places that may be abiotic [17,18].

Take, for instance, the magnificent, 7-km-deep Valles Marineris, one of our solar system's grandest canyons, all of which may be helpfully conserved and preserved using Leopoldian strategies divided into zones inspired by the UNESCO biosphere reserve model [19], which I discuss more fully in Section 8.3. One region of the Valles Marineris International Ecosphere Reserve, the core Preserve, will embody a true Leopoldian baseline ecology and forever will provide scientists with irreplaceable, date-stamped control data. This area will allow only transient human presences to undertake no-footprint science, and otherwise here Mars will be left to be Mars. At the time of this writing, sterilization of everything in the area will be required. Another region within the larger reserve, the Sustainable Reserve, will allow sustainable industry and science while bearing resemblance to a baseline ecology. One more location will be a Leopoldian baseline ecology until it becomes transformed by future human recreation. Given that “parks” are places primarily for human recreation but not necessarily for scientific preservation [12], the recreational area can be called Valles Marineris Park. Because of its Leopoldian method of genesis, the awe-inspiring park will offer a scenic Martian recreation experience almost as if humans never arrived. What a fantastic vacation spot!

By letting Leopoldian baseline ecologies guide our preservation of Mars such as with the Valles Marineris International Ecosphere Reserve described here, we simultaneously may do more rigorous scientific research, more capably identify and protect Martian locations for their own ethereal sakes, better enrich cultural and historical meanings, allow some human use, and provide future vacationers with more primeval settings for their happy getaways. Thus, we can accomplish some quite positive human and environmental goals, but, according to Leopold and Muir's logic, only if we make some haste.

6. The need for speed

One more implication from founding the preservation of Mars on Leopoldian baseline ecologies and Muir's principles highlights that the longer we wait to establish these baseline ecologies, the more we dissipate their power day by day. If we are assembling scientifically-accessible ecosystem time capsules for the future, it benefits future beings, and even some scientists in the present, if we start those time capsules as soon as we can. By moving quickly to establish, through the intergovernmental cooperation that I describe in Section 8, International Ecosphere Reserves on Mars, we enrich the value of those places by setting their baseline ecology origin clocks as early in history as possible. Environmentally, we cannot go back four billion years, but we can set baseline ecology inception times to start before the next day or sol

and commence better science and environmental protection immediately.

Conversely, if we wait until after humans are on Mars, we will have squandered a great historic opportunity to establish critical prehuman environmental control samples and thus will fail to benefit humanity, human knowledge, and Mars itself. To avoid this significant misfortune, we may realize that human beings are never separate from the natural places that they preserve, like the environmental historian William Cronon stresses [20], so that in speedily and effectively preserving Mars, we protect ourselves, our cultures, our knowledge, and our ideals. As a result, while on Mars, we “save from destruction what is best,” as Zahniser wished [11], we also preserve humanity. Therefore, we should establish Martian environmental preservation zones, rationally administered by international governmental cooperation, today. Tomorrow is second-best.

7. Potential ethical objections

Perhaps the environmental ethicist J. Baird Callicott or the astrobiologist Christopher McKay will oppose my use of Leopoldian outlooks on Mars, given that both of these thinkers consider Leopold's influential “land ethic” [8] to be Earthbound. However, their possible objections on this issue do not blunt my position. As I have mentioned, the baseline ecology method that I describe here remains a separate entity from the land ethic and moreover does not include the land ethic's land-as-organism presumption. In this essay, the baseline ecology is a scientific methodology, not an ecosystem morality or metaphysics.

Nonetheless, for the sake of lucidity, I mention that Callicott [21] argues that Leopold's land ethic cannot be applied beyond Earth, for the land ethic to him remains based on a “common evolutionary heritage.” Yet our “common evolutionary heritage” actually began not 4.5 billion years ago on Earth, but with the genesis of our universe 13.7 billion years ago, when there was no Earth. As for McKay [22], his contention that the land ethic, built on the idea of biotic communities, is difficult to apply to a lifeless Mars remains fair as posed, despite the land ethic's respect for geological features. However, if it becomes shown that life exists on Mars, then there will emerge a biotic Martian community to which the land ethic can apply unambiguously, ending McKay's critique. Finally, William R. Stoeger [23] praises Leopold's land ethic for its inherent relationality, which to Stoeger makes it a good choice for application beyond Earth. Thus, because neither Leopold's land ethic nor its organismic presumptions are involved in my overall argument here, and anyway the land ethic may be more applicable to Mars than we currently realize, my thesis persists.

Alternatively, critics may object that ferocious Martian storms can blow contaminants into baseline ecology reserves. To a point, this remains a problem because these landmarks practically cannot be encased in bioprotective shells, and, regardless of practicality, such protection would inhibit ecological free development. But Cockell and Horneck [5] rightly indicate that separating these locations from potential human occupation zones, as with the baseline ecology method, lessens the possibility of windborne contaminants. In addition, Earth biotics may have a much tougher time surviving the dry, radiation-prone surface winds than they do within the more Earth-like Martian subsurface [24]. Establishing baseline ecologies protects special landmarks from this subsurface contamination danger by limiting human activities in those places. Thus, in the worst-case scenario, in the future, the baseline ecology reserves still will provide historical ecological control samples of a sort, even if they become somewhat contaminated through wind action.

If we therefore set aside the rhetoric of political legislation, Earth-centered limitations to ecological thinking, as well as windborne contamination concerns, and return to Leopold's original concept of baseline ecologies in terms of Mars, future generations may thank us for

ing baseline ecology reserves as early as possible. In the end, nothing about Mars seems to bar the baseline ecology method in itself and a dearth of humans there recommends it. The baseline ecology method's inexpensive cost and relatively easy integration into existing United Nations (UN) practices also recommend it, as I now discuss.

8. Policies for implementation

In term of effects on policy, this proposal differs from recent efforts to establish historical parks on our moon and some common economic experiences with the establishment of nature reserves on Earth. Conversely, creating baseline ecologies on Mars dovetails nicely with the contours of existing UN regulations and campaigns, and this good fit affects the path of its possible adoption. Turning first to our moon highlights these important features.

8.1. Parks on our moon

In 2013, United States Congress Representatives Donna Edwards and Eddie Johnson introduced H.R. 2617, the Apollo Lunar Landing Legacy Act, which is a bill that seeks designation of Apollo landing sites as US national historical parks [25]. Given the increased commercial traffic that our moon likely will see in the future, the legislation seeks to protect historical landmarks such as the first lunar human footprint. However, to date, the bill remains dead at the committee level because it conflicts with provisions found within the 1967 Outer Space Treaty (OST). Articles I, II, and VIII of the OST prohibit real estate ownership claims beyond Earth, sovereignty claims beyond Earth, and the extension of jurisdictions beyond our home planet [25]. The establishment of a US historical park on our moon appears to violate all three of these provisions [25]. These OST provisions also challenge a complementary effort to establish Apollo areas as UNESCO World Heritage sites [26] because World Heritage landmarks must be owned by countries [25].

Alternatively, establishing baseline ecologies on Mars as described here takes a fresh approach that engenders no explicit or implicit property, sovereignty, or jurisdictional claims, thus remaining in line with the OST. As I explore again in Section 8.3, in this proposal, no nation or finite collection of nations will claim ownership of Martian ecosystem reserves, just as the Antarctic Treaty System (ATS) manages an international reality that lacks state real estate property [27]. The cooperative yet propertyless environment of the ATS not just contributes to its decades-long success, according to the SETI Institute's Margaret S. Race; also, for space environmental protection, the ATS “provides a workable model that may be emulated with some confidence as the exploration of outer space moves ahead” [28]. More fully, similar to provisions found within the UN's 2001 Convention on the Protection of the Underwater Cultural Heritage (CUPCH) that, for example, protect the remains of the *Titanic* [25], these Martian ecosystem reserves will remain international zones, owned by no one country or limited collection of them, and the UN will serve as the manager for these areas. While not every nation has ratified the CUPCH, the environmental disposition of Syrtis Major arises less politically and economically charged than claims on the Atlantic Ocean sea floor, so hope exists for international agreement on this count.

For clarity, I mention that the historical ecosystem reserve in this proposal that takes its inspiration from the presence of the Viking 1, Pathfinder, and Sojourner spacecraft also will exist as an international ecological area. Nonetheless, the celebration of humanity's cultural history of the exploration of Mars, including by United States spacecraft, will be the point of this specific ecosystem reserve. In this reserve at once, we will save Viking 1, the US achievement, and that region of Mars as much as possible as they were when Viking 1 was active, showing that the baseline ecology method can serve effectively to pro-

tect historical and cultural sites, not just ecological ones. In this way, this baseline ecology method proposal fulfills the goals of those who wish to memorialize this area for reasons of national pride, even if that protection becomes realized through international accord.

In fairness, it must be recognized that under Article VIII of the OST, the spacecraft in this international reserve still will belong to the United States government [29]. Yet it will be in the interests of the United States cooperatively to support this proposal, which protects and spotlights the US historical heritage of early Martian exploration through the international mutual respect that benefits all spacefaring nations, is a hallmark of space exploration efforts and, in this case, provides more secure long-term protection than national legislation. Other countries similarly may wish to have their national space accomplishments on Mars memorialized through this international baseline ecology method, and no obstacle emerges from within this proposal toward reaching that end. In fact, this same baseline ecology approach can be applied elsewhere in the solar system, including on the moon to establish Apollo historical parks that supply extra baseline ecology scientific and environmental gains.

8.2. Economics and nature reserves on Earth and Mars

Besides differing from the effort to create lunar historical parks, adoption of this proposal also reveals some outcomes, especially economic ones, which vary from common experiences when establishing nature reserves on Earth. First, Martian baseline ecologies can be enacted quite inexpensively for now. Today, there are no fences to build, no land parcels to buy, no economic rights of displaced people to fulfill, no park rangers to pay, and, because this proposal arises from the spirit of cooperation, no current enforcement mechanisms to fund. Eventually, enforcement mechanisms must develop at least to deal with private traffic, but because such enforcement at this time is difficult practically to conceive, this proposal accommodatingly leaves such steps to a more informed future.

Because of this lack of other expenses, increasing the scientific and ecological value of Mars today requires only a quality map of the planet and an instrument for drawing ecosphere reserve boundaries on that map. Given that this proposal seeks both scientific and environmental goods, a team of Martian environmental scientists and ethicists should be able to handle the boundary-drawing task quite effectively. Although boundaries within overall reserves delineating Preserve, Sustainable Reserve, and Park areas should be drawn today to maintain some long-term rigor, given our incomplete knowledge, these inner boundaries should remain explicitly malleable right now. For instance, it is difficult at present to know exactly which part of Valles Marineris is best reserved for commerce and which is best suited for recreation. Yet, in concert with the “precautionary approach” of Principle 15 of UNESCO’s Rio Declaration on Environment and Development, which states that a lack of scientific knowledge of a region should not impede its preservation [30], tentatively we can set inner ecosphere reserve boundaries for today while inviting people within a better prepared future to reset them later. Temporal flexibility such as this helps to enable the success of the ATS here on Earth [27], and creating baseline ecologies on Mars as proposed in this essay embodies similar adaptability concerning the Martian scientific and environmental future.

Such flexibility further accrues to a different reason why this proposal diverges from much of Earthly experience with setting aside natural areas: its integration with commerce. This baseline ecology protection method interferes little with future commercial ventures on Mars, in part because only seven specific locations on the planet remain specified for protection, while the strictures of this proposal do not apply to the rest of Mars. Notable landmarks get protected, but the vast majority of Mars remains open for business, being governed by whatever space commercial policies develop over time.

Furthermore, and as I have described, one area within each of our baseline ecologies is reserved for sustainable industry and commerce from the outset. In this way, even protected areas can bend to meet conditions of a commercial future that we cannot foresee currently. The requirement for sustainability within the ecosphere commercial reserves seems not burdensome because sustainability already exists as a pillar of responsible Earth commerce. As one can find in the ATS model [27], in this baseline ecology, system behavior in protected areas becomes regulated, but access remains theoretically open, with this last part’s reflecting commercial desires as well as OST Article I requirements that mandate unlimited entry [29].

8.3. Compatibility with UN practices

While varying from efforts to create historical parks on our moon as well as common Earthly environmental policy experiences, provisions of this proposal alternatively cohere well with current UN regulations and activities. As I mentioned previously, a model by which Martian baseline ecologies can remain stateless international zones appears not only in the ATS but also in the UN’s 2001 CPOCH. This treaty empowers international zones which the UN manages within the deep sea bed [25].

In addition, this Martian ecosphere reserve proposal reflects ideals and structures already in place within UNESCO’s Man and the Biosphere (MAB) program, which intends to defend our natural heritage. In establishing 669 biosphere reserves in 120 countries since 1976 [19], the MAB program meets various resource needs by dividing protected areas into regions of preservation, recreation, and sustainable human industry and commerce. This multiuse method, which reflects Muir’s preservation-and-conservation recommendations [14], inspires a similar approach to the Martian reserves proposed here.

Unlike in current MAB practice, however, I use the word “ecosphere” rather than “biosphere” because this word remains more applicable to potentially abiotic environments. In addition, contrary to the Earthly MAB program but in parallel with the CPOCH and the OST, states will not own real estate within Martian reserves, which instead exist as international zones.

Because of these differences, Martian ecological reserves appear best managed by the UN Committee on the Peaceful Uses of Outer Space (COPUOS), which already administers Martian anticontamination efforts through its COSPAR arm. Indeed, at present, COSPAR’s management includes protection of scientifically interesting special areas [31], much like this baseline ecology proposal seeks scientific protection of delineated environmentally-important spaces. Moreover, UNESCO roots itself strongly in Earth property law, leaving COPUOS better placed for working with the unique elements of space property law. Yet the organic fit with existing MAB program objectives, processes, and agreements makes this proposal conceptually easy for the UN to integrate and manage along with campaigns that already flourish. In other words, COPUOS should enjoy accomplished in-house advisors from the MAB while it advances its own inexpensive yet customized-for-space version of the MAB featuring CPOCH-like international zones on Mars. For now, the management of these COPUOS Martian reserves should not be overly troublesome, because there is relatively little current cost involved.

Of course, international zones cannot be established without the assent of individual nations, so while COPUOS seems best suited to manage these Martian reserves, formal or informal bilateral agreements remain necessary for their inception. As a first step, major spacefaring nations such as Russia, China, Japan, India, the United States, and members of the European Space Agency will need to agree on boundaries for the reserves, the meanings of those boundaries, and funding for the small expense required. Naturally, the more nations that can be included in the agreement, whether spacefaring or not, the better. If

formalized into a treaty, such an agreement instantly enhances the scientific value and environmental protection of Mars.

Problematically, though, such a formal bilateral agreement or series of them could be perceived as a joint territorial claim in space and thus a violation of the OST [25]. Therefore, ideally UN member states will move beyond such bilateral treaties and together empower COPUOS to establish and manage ecosphere reserves on Mars for the reasons that I have mentioned. In this way, the scientific and environmental protection of Mars will reflect the intrinsically international character of space operations while it best preserves the ecological treasures of the Red Planet so that they benefit all of humankind, as Article I of the OST requests [29].

Therefore, what is most needed to bring improved science and environmental protection to Mars today is not significant funding or a substantial policy overhaul but international will. For decades, the UN capably has helped to protect our natural world on Earth, and, as the ethicist William R. Kramer relates, increased extraterrestrial activities create a current need for extending similar environmental safeguards beyond Earth [32]. By working together to reframe existing UN regulations and resources, today, we can increase the scientific, cultural, and ecological value of Mars, thus making the first human footsteps on the planet more environmentally responsible and productive of boons for humanity.

9. Conclusion

The environmental track record of *Homo sapiens* is not to be envied, and at some point, members of this species will inhabit Mars. This situation requires cooperative international governmental action, founded upon bilateral international assent yet ultimately coordinated by the UN Committee on the Peaceful Uses of Outer Space, to enact the environmental preservation of Mars. By following the foundational environmental science method of establishing baseline ecologies that provide historical environmental controls, we can enrich the effects of this preservation now and into the future in terms of scientific, recreational, cultural, and historical, as well as environmental goals. In addition, and quite important, following the principle of establishing baseline ecologies instructs us that we must act with promptness and zeal to benefit humanity by preserving Mars today, precisely because no human yet has walked on that planet.

Conflict of interest

None.

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

References

- [1] NASA, NASA's Journey to Mars: Pioneering Next Steps in Space Exploration, NASA, Washington D.C., 2015.
- [2] C.A. Conley, J.D. Rummel, Planetary protection for humans in space: mars and the moon, *Acta Astronaut.* 63 (2008) 1025–1030 <https://doi.org/10.1016/j.actaastro.2008.03.012>.
- [3] D.A. Weintraub, *Life on Mars: What to Know before We Go*, Princeton University Press, Princeton, 2018.
- [4] J.S.J. Schwartz, Where no planetary protection policy has gone before, In: *Proceedings of Tennessee Valley Interstellar Workshop 2016*, Chattanooga, 2016, pp. 30–36.
- [5] C. Cockell, G. Horneck, A planetary park system for mars, *Space Pol.* 20 (2004) 291–295 <https://doi.org/10.1016/j.spacepol.2004.08.003>.
- [6] C.S. Cockell, G. Horneck, Planetary parks—formulating a wilderness policy for planetary bodies, *Space Pol.* 22 (2006) 256–261 <https://doi.org/10.1016/j.spacepol.2006.08.006>.
- [7] A. Leopold, Wilderness as a land laboratory, in: M.P. Nelson, J.B. Callicott (Eds.), *The Wilderness Debate Rages On*, University of Georgia Press, Athens, 2008, pp. 93–96.
- [8] A. Leopold, *A Sand County Almanac*, Oxford University Press, London, 1949.
- [9] T.W. Swetnam, C.D. Allen, J.L. Betancourt, Applied historical ecology: using the past to manage for the future, *Ecol. Appl.* 9 (4) (1999) 1189–1206 <https://www.jstor.org/stable/2641390>.
- [10] M.W.T. Harvey, *A Symbol of Wilderness: Echo Park and the American Conservation Movement*, University of Washington Press, Seattle, 2000.
- [11] E. Zahniser (Ed.), *Where Wilderness Preservation Began: Adirondack Writings of Howard Zahniser*, North Country Books, Utica, 1992.
- [12] C.W. Allin, *The Politics of Wilderness Preservation*, University of Alaska Press, Fairbanks, 2008.
- [13] H. Rolston III, *A New Environmental Ethics: the Next Millennium for Life on Earth*, Routledge, New York, 2012.
- [14] J. Muir, *Our National Parks*, Sierra Club Books, San Francisco, 1991.
- [15] T. Wilkins, *John Muir: Apostle of Nature*, University of Oklahoma Press, Norman, 1995.
- [16] C.S. Cockell, *Space on Earth: Saving Our World by Seeking Others*, Macmillan, London, 2007.
- [17] M. Gray, *Geodiversity: Valuing and Conserving Abiotic Nature*, John Wiley and Sons, West Sussex, 2004.
- [18] J.J. Matthews, S. McMahon, Exogeoconservation: protecting geological heritage on celestial bodies, *Acta Astronaut.* 149 (2018) 55–60 <https://doi.org/10.1016/j.actaastro.2018.05.034>.
- [19] A. UNESCO, *New Roadmap for the Man and the Biosphere (MAB) Programme and its World Network of Biosphere Reserves*, UNESCO, Paris, 2017.
- [20] W. Cronon, The trouble with wilderness; or, getting back to the wrong nature, in: W. Cronon (Ed.), *Uncommon Ground: toward Reinventing Nature*, Norton, New York, 1995, pp. 69–90.
- [21] J.B. Callicott, Moral considerability and extraterrestrial life, in: E.C. Hargrove (Ed.), *Beyond Spaceship Earth: Environmental Ethics and the Solar System*, Sierra Club Books, San Francisco, 1986, pp. 227–259.
- [22] C.P. McKay, Planetary ecogenesis on mars: restoration ecology and environmental ethics, in: C.M. Bertka (Ed.), *Exploring the Origin, Extent, and Future of Life: Philosophical, Ethical, and Theological Perspectives*, Cambridge University Press, Cambridge, 2009, pp. 245–260.
- [23] W.R. Stoeger, Astrobiology and beyond: from science to philosophy and ethics, in: C. Impey, A.H. Spitz, W. Stoeger (Eds.), *Encountering Life in the Universe: Ethical Foundations and Social Implications of Astrobiology*, University of Arizona Press, Tucson, 2013.
- [24] C.P. McKay, Hard life for microbes and humans on the red planet, *Ad Astra* 19 (2) (2007) 30–31 <https://space.nss.org/ad-astra-volume-19-number-2-summer-2007/>.
- [25] K. Ellis, Preserving Apollo: H.R. 2617 and the creation of the Apollo lunar landing sites national historical park, *Fordham Environ. Law Rev.* 26 (3) (2015) 516–558 <https://ir.lawnet.fordham.edu/elr/vol26/iss3/1>.
- [26] L. Westwood, B.L. O'Leary, M.W. Donaldson, *The Final Mission: Preserving NASA's Apollo Sites*, University Press of Florida, Gainesville, 2017.
- [27] P. Ehrenfreund, M. Race, D. Labdon, Responsible space exploration and use: balancing stakeholder interests, *New Space* 1 (2) (2013) 60–72 <https://doi.org/10.1089/space.2013.0007>.
- [28] M.S. Race, Policies for scientific exploration and environmental protection: comparison of the antarctic and outer space treaties, in: P.A. Berkman, M.A. Lang, D.W.H. Walton, O.R. Young (Eds.), *Science Diplomacy: Antarctica, Science, and the Governance of International Spaces*, Smithsonian Institution Scholarly Press, Washington, D.C., 2011.
- [29] United Nations, *United Nations Treaties and Principles on Outer Space*, United Nations Publications, New York, 2002.
- [30] United Nations, *Rio Declaration on Environment and Development*, 1992 <https://www.un.org/documents/ga/conf151/aconf15126-1annex1.htm>, Accessed 27 March 2019.
- [31] World Space Council, *COSPAR Planetary Protection Policy with Explanatory Annotations*, World Space Council, Houston, 2011.
- [32] W.R. Kramer, Colonizing mars—an opportunity for reconsidering bioethical standards and obligations to future generations, *Futures* 43 (2011) 545–551 <https://doi.org/10.1016/j.futures.2011.02.006>.