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Animal welfare issues in space settlement expeditions

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ABSTRACT

The ongoing debate on space bioethics has thus far focused primarily on issues pertaining to human beings. However, in the existing literature there is a shortage of articles raising the issue of whether animals can be used for space settlement expeditions. Consequently, the aim of this article is to present some initial considerations regarding the ethics of using animals for this particular purpose. Specifically, four potential reasons for involving animals have been put forth. These can be categorised as follows: (1) to use animals as a food resource; (2) to use animals for research purposes; (3) to use animals for company purposes; and (4) to provide new habitats for those animals whose ecosystems on Earth are endangered. Within the afore-mentioned space bioethics debate, the possibility of genetically enhancing human beings has been a topic of considerable discussion. For this reason, the article also addresses the ethical implications of genetically enhancing the animals used in space expeditions. A Welfarist approach has been adopted to determine which uses of animals are ethically permissible and which are not, with the understanding that any use that compromises the animal's ability to lead a good life is unacceptable. Accordingly, mere survival is not ethically relevant.

1. Introduction

Both scientific and ethical research have begun to address the possibility of humans' undertaking expeditions to settle on planets other than the Earth (Szocik et al., 2021; Garasic, 2021; Balistreri & Umbrello, 2023). However, it is possible to assume that future space expeditions and settlement projects will eventually also involve animals. For instance, recent research has focused on the feasibility of using non-human animals as a food source on multi-generational ships (Marin et al., 2018) and on non-terrestrial surfaces like the Moon (Przybyla, 2021). For this reason, it is worth investigating the ethics of using animals in space settlement expeditions, mostly because, to the best of my knowledge, this is one of the earliest articles to address the ethical implications of such a scenario (see also O'Brien, 2024). Therefore, the aim is to present some initial insights regarding the ethics of using animals for space settlement expeditions and to examine the question of whether this scenario is ethically permissible. Although it is not possible to speak of a human presence, it is reasonable to argue that space is characterised by a high level of human activity. In recent decades, humanity has indeed succeeded in colonizing the environment beyond Earth through the sending of probes and satellites and the construction of a stable space station, which have resulted in the creation of a significant amount of debris and pollution (Skibba, 2024). Conversely, space is the only environment known to lack any sign of non-human animal activity, an unparalleled occurrence in history. Given this unique scenario, it is necessary to provide an ethical analysis in order to anticipate potential developments and related implications. This analysis should consider the evaluation of a range of potential scenarios, with a view to identifying any potential concerns that

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may arise prior to their implementation (Zohny, 2021).

In order to address the afore-mentioned question, this article adopts a Welfarist approach. Consequently, the aim of this study is to examine the impact of using animals in space expeditions on their welfare. It is therefore not a question of precluding any use on the basis of a recognition of animal rights, but of determining whether said use impairs the animal's capacity to experience and lead a good life. Of course, what the expression "good life" actually means would remain to be determined. However, for the purposes of this article, it is sufficient to refer to the discussion already provided by Sandøe (1999) and Hauskeller (2018).

Accordingly, Section 2 examines four potential reasons for carrying animals to non-terrestrial settlements. The first pertains to the use of animals as a food source, whereas the second relates to their employment in biomedical research. The third scenario encompasses the possibility of involving companion animals. The fourth and final option is the most challenging and speculative and concerns the possibility of providing new habitats on other planets for those animals whose ecosystems on Earth are endangered. Section 3 addresses the welfare issues associated with the four potential reasons outlined. Section 4 builds upon the existing debate surrounding the relationship between space expeditions and humans by examining the potential for genetically enhancing animals. In response to the challenges posed by extraterrestrial environments, there has been a great deal of discussion about the possibility of modifying the human genome (Szocik & Braddock, 2019; Szocik & Tachibana, 2019; Szocik, 2020; Szocik et al., 2021; Balistreri & Umbrello, 2023). As Szocik asserts, enhancing human beings represents a moral duty, given their inherent vulnerability in space or on non-Earth planets. It may be reasonably assumed that the same problems would also arise for animals. However, the possibility of genetic alteration is not the only alternative available: terraforming is also a feasible option. It could be stated that both solutions present advantages and are not mutually exclusive (Balisteri & Umbrello, 2023). Section 5 concludes with a few final remarks. In particular, mere survival is rejected as a constitutive element of animal welfare, especially in a space settlement expedition context. Furthermore, the principle of the moral non-exceptionality of space is affirmed, which implies that space animal ethics must be grounded on terrestrial animal ethics.

Finally, two aspects of this article are worth noting. Firstly, its focus is on complex animals, particularly mammals, and it excludes consideration of invertebrates such as tardigrades, which have already been used in space research (Weronika & Łukasz, 2017). Secondly, this article does not assume that the Earth is no longer capable of sustaining life, and thus that off-Earth settlements are the only viable option.

2. Settling off-Earth planets with animals: Four reasons

As has already been stated, four potential reasons may be posited for using animals in future settlement missions to planets beyond Earth, primarily to provide inhabitants of new planetary settlements with animal resources for food. For instance, establishing an extraterrestrial farm could be deemed essential. Research on aquatic vertebrate breeding is already being carried out to provide "food sources for crewed missions using in situ resources and converting these into the food necessary to sustain life in space" (Przybyla, 2021, p. 1). One could argue that "the researchers noted that raising farm animals for dairy and meat would not be practical on Mars in the near term because of [for instance] the challenges of shipping them across space" (Choi, 2019). Of course, the issue under discussion primarily concerns the potential advancements that could take place in the future, rather than existing possibilities.

Animals are also set to be employed in scientific experiments involving space pharmacology, surgery and the creation of countermeasures that guarantee astronaut safety in the course of an extended space journey. Given the limitations of terrestrial analogues, using animals is evidently a viable option for such investigations. Due to the uncertain survival of pregnancy, childbirth, and growth in space, animal models must be assessed before considering the application to humans. Therefore, the second purpose of using animal models in a space environment is to enhance understanding of biological mechanisms in an extraterrestrial context.

The third reason for allowing animals to be used by humans in their space settlement expeditions would be to provide them with companions (Pozzebon, 2023). Numerous studies have highlighted the positive effects of animals on human well-being. They have been found to alleviate feelings of depression and sadness while also reducing stress caused by adversities (Smith, 2012; Koda et al., 2016; Brooks et al., 2018). In a new world, settlers will undoubtedly encounter extremely stressful situations. Therefore, the presence of companion animals would be greatly valued by humans as they would offer a reminder of Earth, preventing them from feeling disconnected due to their distance from home. However, there may be debates surrounding the viability of having companion animals beyond Earth as this would require veterinary knowledge and facilities (Boro et al., 2016).

The fourth and final purpose is arguably the most speculative. Nonetheless, Szocik's perspectives on the ethical ramifications of human space exploration offer grounds for a discussion regarding animals. Szocik contends that it is important for humans to consider themselves as a multi-planetary species. Considering the possible future settlement of space by humans, Szocik and Reiss (2023) argue that space should be regarded as a natural area for the broadest range of human activities, while at the same time guiding development. Carrying animals for the purpose of settling on new planets should be prioritised, with the goal of providing them with fresh opportunities and new spaces for self-fulfilment. "Animal ethics has received a lot of attention over the last four decades. Its focus, however, has almost exclusively been on the welfare of captive animals, ignoring the vast majority of animals: those living in the wild" (Moen, 2016, p. 91). Wild animals' suffering arises from various causes, including predation or, more generally, the tough living conditions in their natural environment (Moen, 2016; Tomasik, 2015; Palmer, 2021, pp. 12358). One of the challenges is that wild animals continuously lose significant parts of their ecological niches due to human expansion. In this respect, the World Wide Fund for Nature (2023) (WWF) asserts that:

Habitat loss poses the greatest threat to species. The world's forests, swamps, plains, lakes, and other habitats continue to disappear as they are harvested for human consumption […]. Without a strong plan to create terrestrial and marine protected areas important ecological habitats will continue to be lost. […] [Habitat loss] is identified as a main threat to 85% of all species described in the

IUCN's Red List (those species officially classified as "Threatened" and "Endangered"). (WWF).

Therefore, one option could be to establish the protected areas mentioned by the WWF on the new extraterrestrial planet. Furthermore, the planet, which has not yet experienced significant human occupation, could facilitate large areas for relocation projects and the introduction of wild animals.

3. Settling off-Earth planets with animals: Is it ethically permissible?

It is important to note that the issues discussed in this section may not exclusively relate to space. However, this would not be a problem if we accepted the thesis put forth in this article and discussed in greater detail below, namely that space is ethically non-exceptional (Garasic, 2021; Balistreri & Umbrello, 2022). This implies that space cannot be conceptualised as a dimension that is morally autonomous from the accepted principles of Earth. "The distinction between conditions on Earth and conditions in space appears arbitrary not only at the normative level […] but also on the descriptive level. […] The borders (that is, the walls), that is, are always conventional and can always be moved" (Balistreri & Umbrello, 2022, p. 319). Hence, the same ethical conclusions that hold true for Earth apply to other planets as well. Moreover, if the circumstances of the new planet are the same as those on Earth, as a result of gene editing and terraforming, then identical ethical considerations should be applied.

The first scenario is when animals are used as a food source. This first use is ethically problematic if the aim is to consider as permissible only those reasons where animal welfare is not compromised. Even the practice of "humane farming" cannot be considered an improvement, as the animals would still be subjected to mistreatment because they would still be killed. According to Kasperbauer and Sandøe, "the idea that death harms an animal has traditionally been kept separate from issues about animal welfare. This is because the death of an animal has been viewed as a post-welfare issue" (Kasperbauer & Sandøe, 2015, p. 23). Although animals were killed without causing them any suffering, their death would still be detrimental to their welfare. This is because killing them would deprive them of future welfare experience and frustrate their future desires. A similar situation arises when animals are used as models for research. Animal suffering per se may not be morally decisive if it is outweighed by benefits, such as those for human consumption. However, it is important to note that the aim is to investigate scenarios where animals have the possibility of leading a good life, which is not the case in their use for food or research. As O'Brien claims, "if we abolish animal exploitation before we begin colonizing space, this will reduce the possibility of spreading animal exploitation beyond Earth" (2024, p. 17).

The third scenario to consider is whether it would be ethically permissible to carry animals on non-Earth planet settlement missions to serve as companions. Would it be justifiable to burden animals with accompanying our species into space and enduring the hardships that come with it? Would it be permissible to bring companion animals to a harsh environment merely for companionship? The use of companion animals does not seem to pose the same critical concerns as the preceding scenarios. We are discussing animals that are not used for food or for research purposes, but are cared for in human households, with all the comforts coming with that. However, strong views have been expressed by Danten (2015), who suggests that the bond between humans and their companion animals mimics that of a master and slave. While Danten acknowledges that animals used in the food industry endure worse conditions than their pampered counterparts at home, the author argues that the differentiation in treatment is akin to the distinction made between house and plantation slaves during the enslavement of African-Americans. At the same time, Kendrick (2018) argues that companion animals may suffer if mistreated, which effectively changes their status from slaves to victims. Animals would inevitably be seen as the possessions of humans, regardless of the level of freedom granted to them or the degree of care afforded to their welfare. Regardless of the terminology used to describe them, companion animals may be considered objects of property, which would potentially endanger their welfare. Therefore, human attitudes towards companion animals pose this risk. When humans regard their companion animals as equals within the household, providing them with the necessary resources and care to ensure a good quality of life, there is no basis for asserting that having a companion animal would impair their welfare. However, even on Earth, this is not always the case and companion animals are not always guaranteed a good life.

The preceding discussion has been of a "terrestrial" nature. Regarding space travel and off-Earth settlements, specific issues must be addressed. The confinement of companion animals in cramped spaces during space travel and at the early stage of settling on a new planet poses a significant challenge (Pozzebon, 2023). For instance, what care would dogs and cats receive in spaceships or habitats built on the new planet? Furthermore, accommodating animals in limited space requires implementing appropriate measures. For example, "it would be much easier to keep dogs and cats in just one place, rather than having one pet per family. This would also help in maintaining a stable number of animals regardless of how many human families are on board" (Pozzebon, 2023, p. 110). This circumstance could present issues for animals such as cats, who face difficulties living in spaces that inhibit their ability to engage in activities and behaviour suitable for their species (Amat et al., 2016). Another issue concerns the potential for conflicting relationships with other animals. Particularly pertaining to settlement expeditions, issues might arise during the earliest phases of the project. It should be noted, however, that said problems may be resolved once both gene editing and terraforming are accomplished and refined. At that point, the emphasis would shift towards ethical concerns relevant on Earth.

It could also be argued that using animals sent into space as companion animals is ethically permissible, provided they are strays or have been rescued from unpleasant situations, such as research laboratories. This would improve the animals' quality of life. However, a broader discussion on the management of stray animals would be necessary to address any objections. For instance, a welfarist standpoint does not necessarily posit that animal possession would be preferable to abandonment; it may be beneficial in certain circumstances, but not universally. Instead of promoting the animal's freedom and improving its condition, humans may rescue it from a stray or abandonment situation only to force it into a role as a companion. Humans who engage in this activity may display a lack of significant ethical consideration towards the animals and their distress. In conclusion, it would still be debatable whether it is ethical to include companion animals in space settlement expeditions, owing to the uncertainty concerning their welfare in such circumstances.

Finally, the last reason would be to facilitate the relocation of animal species whose habitats on Earth have been compromised. While this appears to be driven by sound ethical principles, it is nonetheless important to consider the potential implications of the proposed reason. Apart from considerations pertaining to the necessity of terraforming or gene editing procedures in enabling life on extraterrestrial planets – which will be discussed in the following section – a primary welfare challenge for wild animals would be associated with the problems of predation and illness, as has already been noted. O'Brien argues that the proliferation of wild animal life to other planets represents one of the easiest ways to worsen the future for animals (O'Brien, 2024). This sparks a discussion about the ethical permissibility of intervening in the wild to prevent suffering, such as imposing restrictions (even genetically) on freedom from predators for certain species (Nussbaum, 2006; Pearce, 2009). O'Brien contends that eradicating natural suffering, be it through gene editing or other methods, would result in greater expenses than deterring its propagation to other planets. Populating a new planet with wild animals can only occur under conditions that promote animal welfare. It is clear that the solution to the suffering of wild animals on planets other than Earth – namely, not bringing them into space expeditions – is much simpler than its solution on Earth. For instance, with regard to the issue on Earth, some may even propose a radical solution, such as the sterilisation of predators. However, this discussion is beyond the scope of this article.

It could be argued that ethical concerns regarding suffering in nature should not be raised. Rolston (1988) contends that moral repugnancy should not be assigned to suffering resulting from natural processes, such as predation. Only those forms of suffering that are unnatural and caused by human intervention warrant censure and prevention. Animals may replicate natural processes (e.g. predation) on planets other than Earth, but it remains uncertain whether these processes should be deemed truly natural beyond our planet. In the context of space settlement expeditions, any resulting suffering should be attributed to human activities. Indeed, it would be humans who would release animals, including both prey and predators, onto the new planet. In this instance, the suffering in question would be morally relevant on the grounds that it is no longer caused by natural processes (naturogenic), but by human action (anthropogenic) (Johannsen, 2021). By releasing or creating the predators, human settlers would "enable them to inflict harms on other animals" (O'Brien, 2022, p. 892). In any case, whether the cause is naturogenic or anthropogenic, this fourth reason is also open to criticism, as it would still result in suffering for the animals involved.

4. Enhancing animals and terraforming planets

Most of the animal welfare concerns raised so far could be categorised as "terrestrial". Indeed, it is the case that this series of issues would not be unique to another planet, but has already been identified on Earth. It is evident that, unless Earth-like planets capable of supporting life as we know it are discovered, terrestrial organisms will remain unable to survive outside the Earth's atmosphere or a spaceship. In this scenario, the implementation of genetic enhancement and terraforming processes may be the optimal solution to the survival challenges that terrestrial organisms would face in space. For example, Szocik, Norman et al. (2020) write that, "while substantial genetic enhancement carried out on Earth for the purposes of those who will live their lives on Earth seems to be more of a choice than a medical necessity […] there are good reasons to believe that the substantial enhancement of future Mars astronauts might be necessary to increase their chances of survival" (Szocik, Norman et al., 2020, p. 1225). As outlined by Szocik, Norman et al. (2020), the enhancement of humans in the context of space settlement expeditions is even regarded as a moral duty. Consequently, if it can be assumed that a number of other animals will be accompanying humans on these missions, there is no justification for not extending this moral duty to them as well. Genetic enhancement may facilitate animals' adaptation to the harsh environment of the new planet, for instance by improving particular capacities such as resistance to radiation or acclimatizing to different levels of gravity. This kind of genetic enhancement may be defined as "remedial", "to signify that such interventions would aim to help animals facing anthropogenic challenges to deal with those challenges, for the sake of those animals themselves" (Bovenkerk & Kramer, 2022, p. 206).

It could be argued that gene editing presents various scientific and ethical challenges (e.g. the risk of unintended effects) and it would be simplistic to depend on it as the sole solution for ensuring animal welfare in space. As previously stated, another potential solution would be terraforming. It is evident that even this option cannot be viewed as a standalone solution but is inextricably linked to that of genetic enhancement. However, although this may be considered as a more easily implementable approach than gene editing, it too would prove challenging to realise. Initially, the most likely scenario would be the construction of a space-limited biosphere, similar to the International Space Station, on a new planet. However, it should be noted that confining the animals to a limited and controlled space could also have an adverse effect on their welfare. It could be argued that humans do not typically allow farmed animals, research animals and even companion animals on Earth free access to the outside world. However, as previously stated, a confined space prevents companion animals such as cats from engaging in species-typical behaviours, thereby creating a situation that is inherently problematic with regard to their welfare. A similar issue would arise in the case of wild animals. The imposition of a restricted environment on these animals would not only be detrimental to their welfare, but also unnecessary, given the initial reason for carrying them in space settlement expeditions. Without successful intervention, both in the environment and with regard to gene editing, animals would rely on humans, potentially creating a dependence mechanism. It is not difficult to picture that, in a cramped environment like the initial settlement on a different planet, human interests will be given priority over those of non-human animals inhabiting the same space. The experience of living in a settlement on a planet during the earliest stages would be incompatible with the prospect of having a good quality of life. Therefore, this scenario could at least come to fruition when both gene editing technologies and terraforming projects have been fully developed.

In addition to the discussion of enhancement as a potential solution to living conditions in space and on non-Earth planets, gene editing could also be employed to address the welfare issues that have previously been outlined in Section 3. For instance, there is a broad discussion about the possibility of genetically disenhancing food and research animals by disabling their capacity to feel pain or suffering (Thompson, 2008; Shriver, 2009; Palmer, 2011; Ferrari, 2012; Henschke, 2012; Schultz-Bergin, 2014; Shriver &

McConnachie, 2018; Devolder & Eggel, 2019). At the same time, there are studies aiming to identify the genetic basis of certain animal behaviour, such as fear and aggression (Zapata et al., 2016; Sarviaho et al., 2020; Shan et al., 2021). This would provide the opportunity for the genetic modification of companion animals (Taylor et al., 2022), which could facilitate a more rapid domestication process and enable the animals to live in contexts with a limited environment, such as in a off-Earth settlement or in a spaceship (Pozzebon, 2023), without the emergence of welfare issues. Finally, the potential for genetically reprogramming predators (Pearce, 2009) so that they are no longer such is being discussed as part of a wider debate concerning how to address welfare issues for wild animals, with emphasis on the suffering that can result from the existence of predators. However, these gene editing proposals are not viable options that can be immediately embraced; nor are they devoid of moral ambiguities and welfare concerns such as undesired effects and unintended mutations.[2] The prospect of gene editing would not represent a guaranteed improvement in animal welfare, but rather present further critical issues for consideration. These would be in addition to those already raised. Considering that even the resolution of the issues pertaining to gene editing and the adaptive challenges that would be encountered in the initial phase would not alter the conclusions that have already been reached, we must ask ourselves if it is worth questioning whether the debate surrounding these projects is as meaningful on another planet as on Earth, where the issues they seek to address already exist. Would it not be more effective to focus on preventing the occurrence of these issues by avoiding the introduction of animals on planets other than Earth?

5. Conclusion

Two final issues are worth considering. Firstly, although gene editing and terraforming may alleviate survival concerns for the initial settlements on other planets, life off-Earth is still expected to be unfavourable for maintaining a good quality of life. The ethical dilemma of living in space, irrespective of the location (i.e., whether it is a new planet or a generational ship), is not inherently tied to any particular modality for survival. Rather, it is linked to the challenge of having a fair opportunity to lead a good life.

This article considers the possibility of involving animals in future space programs. The likelihood of new generations of animals carried and used in space is considered. However, it must be regarded as ethically impermissible in the absence of the opportunity for the animals to lead a good life. There could also be the risk of overestimating the quality of their life, thereby assuming that it holds value, when in reality the situation is different. It is important to emphasise that the question of animal survival is not the determining factor. Mere survival lacks intrinsic moral value and can result in a life that is not worth living or full of suffering, a concern in both terrestrial and extraterrestrial environments. The rejection of the moral significance of mere survival is in this case related to the fact that animals, unlike humans – at least the first generation of humans – do not have the capacity to make an autonomous decision. Only those who have made a conscious decision to embark on a space expedition should face the potential risks to their welfare in a living environment that would only guarantee survival – at least until genetic enhancement and terraforming projects have successfully established favourable living conditions on other planets that are comparable to those already occurring on Earth. However, one should also consider the welfare issues associated with the use of the animals in question and the implementation of gene editing proposals, as previously mentioned.

Secondly, the fact that animal suffering already occurs on Earth does not necessarily imply or morally justify its occurrence on another planet or in outer space. The argument put forth is that space is morally non-exceptional (Balistreri & Umbrello, 2022). The question at hand is whether it is ethical to settle extraterrestrial planets with animals. Since there is extensive use and exploitation of animals on the Earth, it could be argued that one should not demand significantly different treatment for them on an extraterrestrial planet. However, it is important to note that acceptability should not automatically be assumed for what currently exists (i.e., the 'real' is not necessarily 'rational'). However, when it is asserted that space does not denote a state of ethical exceptionalism concerning Earth, this should not only imply that the principles applicable on Earth must inevitably be applicable in space. It is also possible to adopt a different perspective, maintaining that the same moral tenets that relate to other planets – specifically, that we should not impose cruelty on animals – should equally apply to Earth. Consider the following example. It has been previously stated that the development of farms on new planets could be considered essential. One might argue that it is not essential to have an animal-based diet, given the potential for a plant-based one on the new planet. However, the principle of non-exceptionality of space implies that what exists on Earth could also exist on another planet. The afore-mentioned reversal of the principle of non-exceptionality thus acquires greater meaning in this context. The assumption that space is a non-exceptional entity allows us to extrapolate that the moral principles which apply in space must also apply on Earth. Furthermore, the concept of space as a "blank canvas"[3] allows us to consider how the treatment of animals on a new planet could inform the treatment of animals on Earth, thus highlighting the wrongness of the current moral *status quo* on Earth. Even if the reason is that it is perhaps easier to implement, by affirming the possibility of a plant-based diet on a new planet we are stating how the same diet is also possible on Earth. If one then considers that a plant-based diet is also more ethical, as it does not involve animal suffering, it seems reasonable to conclude that the same moral principle must also be accepted on Earth.

If we consider that the ethical goal is to grant animals a good life, by overcoming non-Earth issues through gene editing and terraforming, the conditions in space would be similar to those on Earth. It could be argued that there is no indication that our exploitative relationship with other animals on Earth would not persist beyond the planet. Given that this assumption holds true, the discussion on terrestrial animal ethics is even relevant in extraterrestrial settings. We can also add, in agreement with Johnson-Schwartz et al. (2023), that our awareness of racism, sexism and other forms of discrimination necessitates the formation of novel

[2] For further information on the ethical implications of these gene editing proposals, please refer to the references provided.

[3] I would like to thank an anonymous reviewer for suggesting this metaphor.

societies that reflect this understanding. What could space exploration be like if we also considered the welfare of animals? How should we alter our approach to space exploration? However, developing plans to mitigate this issue is beyond the scope of this article, which aims to introduce the ethical dilemmas surrounding the use of animals in off-Earth settlement expeditions – even though these problems cannot be ignored. Although there may be differences in the ways in which animals are treated in space settlement expeditions, for instance companion animals may be less adversely affected than food animals, it cannot be assumed that animals taken on such expeditions will not experience negative impacts on their welfare. It can be argued that, even for the companion animals' ability to lead a good life on Earth, the possibility of this capacity's being undermined is an ever-present concern. However, when this is a result of human action, it provides a more detailed insight into the manner in which they are treated on Earth than into the manner in which they should be treated in space. Currently, the ethical considerations regarding animal welfare in space exploration extend beyond the conventional terrestrial concerns (e.g. the exploitation of animals for food and research) to encompass those relating to the adaptation of living organisms to the space environment. As long as both scientifically and ethically successful enhancement projects (e.g. in the form of genetic modification) and terraforming projects (e.g. in the form of habitat construction) remain unattainable, the only ethical course of action is to prevent the implementation of all complex animal-based space missions. However, even if the extraterrestrial challenges were resolved, this would not alter the conclusions that have been reached regarding the terrestrial welfare concerns.

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Mattia Pozzebon: Writing – review & editing, Writing – original draft, Investigation, Conceptualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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