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Space-Based Genetic Cryoconservation of Endangered Species

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SPACE-BASED GENETIC CRYOCONSERVATION OF ENDANGERED SPECIES

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Genetic materials of endangered species must be maintained, for cryoconservation, permanently near liquid nitrogen temperatures of 77 K. Due to the instability of human institutions, permanent safety is best provided at storage sites that maintain passively the needed low temperatures, and provide barriers to access. The required conditions are available in permanently shaded polar lunar craters with equilibrium temperatures of 40 - 8- K, on the moons of Saturn, and unshielded storage satellites. A genetic depository can be incorporated readily into planned lunar programmes.

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1. Introduction

Over the next 50 years, 15-30% of the estimated 5-10 million species may disappear due to human pressures. The losses include hundreds of vertebrate, hundreds of thousands of plant and over a million insect species [1]. The gene pools of many human ethnic groups are also threatened. For many animals, adequate conservation of habitats is unfeasible, and active breeding programs cover only 175 of the many thousand species threatened [2]. The genetic heritage of the living world, accumulated during aeons of evolution, is being wasted in a short period.

Against such losses, scientists are starting cryopreservation programs of genetic material in tissue samples, semen and embryos [3-6]. However, funding is already tenuous. During centuries, incidents of war, sabotage, disasters, economic depression or just a loss of interest are bound to happen. Even a brief disruption of the permanent refrigeration can destroy the samples, and this prospect discourages cryopreservation programs. Secure preservation requires remote sites immune to such disruptions, at locations where the samples can survive periodic abandonment and remain stable indefinitely at natural temperatures around 80 K.

2. Setting Forth the Suitable Sites

No terrestrial sites satisfy these requirements. However, the required equilibrium temperatures exist at lunar polar craters, or at more remote planetary sites that can be used for long-term backup storage. About 0.5% of the total lunar surface area is estimated to be permanently shadowed and remain below 100 K. Thermal balance calculations suggest steady-state temperatures of 40 - 60 K at the shadowed centers of polar craters [7]. The lunar sites are safe from earthquakes due to the low lunar seismic activity, with an average of five events per year with Richter magnitudes of only $2.2<m<4.8$ [7]. At these sites, burial in one meter of the regolith will protect against the solar wind, solar and galactic cosmic rays and micrometeorite impact [8].

Other planetary locations with equilibrium temperatures about 70-90K exist on the moons of Saturn [9]. The atmosphere of Titan with a surface pressure of 1.5 bars can protect from space vacuum, but prevents easy access and retrieval, and the possible surface cover of liquid N_2 is mechanically unfavorable for retrieval. Ease of retrieval favors small, low-gravity moons such as the high-albedo Enceladus with an average temperature of 70 K, or Phoebe, whose large distance from Saturn (1.3 x 10^5 km) and small size 220 km diameter) allows a small escape velocity.

Feasible deposits may be established also on storage satellites in Earth orbit. Shields for thermal insulation and from ionizing radiation can be provided, using shields equipped with passive attitude control by solar sail devices. More simple and secure, but harder to retrieve storage satellites, may be deposited in Solar orbit at about 10 au where equilibrium temperatures are around 80 K.

At lunar or planetary sites, samples will be subject to space vacuum, with at most 2 x 10^5 particles/cm^3 in the lunar environment [7]. Although some microbial material can survive space vacuum and low temperatures for several months, tissues from higher plants and animals should be encapsulated, in addition to the glycerol cryoprotector, against dehydration that can disrupt hydrophobic bonds in membranes, and induce conformational changes and crosslinks in DNA and proteins [10].

3. Requirements for Restoring Endangered Species

To restore an endangered species with viable genetic diversity, material from 20-30 unrelated individuals is regarded as minimum [11], and 0.1 g material from each founder individual can be sufficient using advanced genetic techniques. Using cryopreservation, it may not be necessary, or even desirable to extract DNA. Whole cells or small tissue samples will be easier to prepare for conservation, and to clone back later. To preserve microbial fauna, it is not even necessary (or possible) to identify each species now but microbial filtrates from various habitats such as soils, lakes, oceans and those living on other organisms, can be preserved.

The germplasm or tissue samples of one million endangered species can be accommodated in a payload of 2,000 kg. At expected future launch costs of $1,000 - 10,000/kg, the genetic heritage of one million endangered species can be stored in permanent safety at the cost of $2 to 20 million, or only a few dollars per species. Secure permanent space-based storage will require a smaller one-time cost than that required from more vulnerable terrestrial storage for only a few decades.

Lunar sites appear to best combine physical features with feasibility and security of access. The required transport of 2,000 kg is comparable to the proposal Lunar Cluster Telescope and less than the Large Lunar Telescope or the Lunar Synthesis Array [12]. Construction of a required shallow underground vault of 10 m^3 is less demanding technologically than the construction of lunar observatories or permanent bases. Therefore, the genetic storage program can be incorporated at little extra engineering or economic costs into lunar programs planned in the next 20-40 years. This time frame allows collection of the genetic material.

Even before the permanent storage sites are constructed, payloads of the genetic collections can be soft-landed into the cold craters, and deposited in shallow burrows by robots. When humans return to the Moon, these collections can be transferred to the permanent depositories.

In addition to plant and animal species, the genetic material of human groups is also being lost as populations disperse and intermix. This material is important for the understanding of human evolution, history and biology. Genetic materials of vanishing human groups can be also preserved in space-based depositories.

4. The Philosophy of Space-Based Cryoconservation of Endangered Species

Conservation of endangered species is a popular program. Cryoconservation can add an important ethical component to the space programme and help raising public support. Conversely, the permanent safety of the genetic material can also make cryoconservation itself more attractive and fundable. Many nations may wish to participate to secure the genetic heritage of their unique biota and ethnic groups.

The genetic heritage unites and enriches the living world, and preserving it is a top ethical priority. Until habitat losses are controlled, cryoconservation may provide the best change to secure and eventually revive many endangered species. For this purpose, space-based depositories can provide the most cost-effective and secure means for permanent storage of irreplaceable genetic materials.

References

1. B A Wilcox, "1988 IUCN Red List of Threatened Animals", Gresham Press, Old Woking, Surrey, 1988, pp 12-16.
2. LM DeBoer, "Biotechnology and the Conservation of Genetic Diversity", eds H D M Moore, W V Holt and G M Mace, Claredon Press, Oxford, 1992, pp 5-16.
3. M E Soule, see ref. 2 pp. 225-234.
4. R A Adams, *Diversity*, **8**, 23 (1992).
5. J S Mattick, E M Ablett and D L Edmonson, "Conservation of Plant Genes", Academic Press, 1992, pp 15-35.
6. W V Holt, see ref 2, pp. 19-36.
7. B H Foing, *Adv. Space. Res.*, **14**, pp. 9-18, (1994).
8. T Entrenaz, J P Bibring and M Blanc, "The Solar System", Springer-Verlag, New York, 1990, p. 150.
9. See ref 8, p 226-229.
10. K Dose, *Adv. Space Res.*,**6**, pp. 307-312, (1986).
11. T J Foose, R Lande, R Flesness, G Rabb and B Read, *Zoo Biol.*, **5**, pp 139-146 (1986).
12. J P Wetzel and S W Johnson, *Adv. Space Res.*, **14**, pp. 253-257, (1994).
13. M Meot-Ner (Mautner) and G L Matloff, *JBIS*, **32**, p. 419, (1973).
14. M N Mautner, *JBIS*, **48**, p. 435, (1995).