

Rise and Fall of the Biosphere Project

Brief Timeline

- July 1984 joint venture created to build Biosphere 2 (Biosphere 1 is planet earth)
- 1987 building site selected and foundations dug 30 miles north of Tucson, Arizona
- September 1991 eight crew members enter Biosphere 2 for long study. Millions watch worldwide
- Winter 1991-2 carbon dioxide levels rise to about 3400 ppm, due to reduced photosynthesis
- May 1992 Unpredicted decline of about 0.3% oxygen per month discovered
- September 1992 crew of Biosphere 2 celebrate first year inside
- January 1993 oxygen has to be added to Biosphere 2 to bring atmospheric level up to 19%
- Biosphere is no longer a closed system
- September 1993 first crew leave after two year experiment, hungry and depressed
- 1994 second crew of seven sealed inside for six months
- April 1994 Biosphere 2 fails due to noxious build up of nitrous oxide and poor water quality
- January 1996 Biosphere 2 is handed over to Columbia University for five years
- September 2003 Columbia University withdraws from project
- Today Biosphere is a visitor centre and tourist attraction

Aim of Biosphere

Conceptually, the Biosphere 2 project grew out of the need to know how life could be maintained in biospheres from the smallest (space capsules) to the largest (planets).

Biosphere 2 was designed to be an artificial environment complete with a desert, a rainforest, and an ocean, a miniature, albeit not perfect, version of the earth. This mini-Earth, was the world's largest enclosed ecological life-support system.

Summary of project

The first inhabitants (Biosphereans) entered the Biosphere 2 structure in September of 1991 as pioneers and emerged two years later hungry and depressed. Life inside the Biosphere wasn't as easy or as rosy as originally thought. A little over a year into their stay, the oxygen levels inside the structure dropped dramatically to about 14% rather than the nominal 21% found on Earth. There was not enough oxygen to sustain life. Oxygen from the outside had to be pumped in. Unfortunately this meant that the system was no longer closed; it had become an open system.

Biosphere 2 was only a model of the earth at a very simplistic level. It was a controlled model attempting to test various hypotheses regarding the Earth's functioning. The simplicity undoubtedly escaped notice by the general public, which was expecting many more successful results. Expectations ran high and even though the project team learned much, the public perceived it as a failure.

The conditions that evolved in this experiment of self-containment were definitely not favourable for humans, nor were they for most animals. In this sense, the initial experiment failed. But the engineering design of the building was indeed a success. The degree of material closure and of self-sustainability of artificial ecosystems attained in this project had never been reached before and will probably not be reached again without substantially stronger funding for such a venture.

Physical description of Biosphere

Biosphere 2 covers a footprint of 1.6 Hectares (3.15 acres). Five natural and two human-made biomes are included: tropical rainforest, savannah, marsh, marine, desert, intensive agriculture and human habitat. The system was designed to admit maximum possible sunlight for plant growth, to permit electricity import, and to facilitate heat exchange with the surrounding Earth environment.

Glass used was double-layered, heat-strengthened glass, with a plastic layer sandwiched between the layers, making the glass resistant to breakage.

The human habitat is a 2600 square meter five-story structure which represents an urban or city environment with public spaces and some private spaces for each crew member. This biome is the one zone within Biosphere 2 constructed primarily of opaque metal rather than glass panels. It houses offices, analytical laboratory, medical facility, machine and wood shop, communications and

environmental monitoring terminals, as well as kitchen and other accommodation for resident researchers.

Untreated wool and cotton were selected for fabric applications, including wool panels on the interior of human habitat walls and wool carpeting throughout the human habitat for noise reduction. Because of the low ratio of plants to human occupants in this biome, build-up of CO₂ was a concern; therefore, 'fresh' air from the Intensive Agriculture was vented through the habitat.

Cost of the project

Biosphere 2 was financed by a Texas billionaire (Edward Bass) and cost approximately \$200 million, far more than any university or government would have been willing to spend.

Humans enter the Biosphere 1991

It was inhabited by eight scientists, who for two full years, although still connected to the outside world through telecommunications systems such as email and phone, were physically isolated from the planet and world in which we inhabit everyday. For those two years each biospherian had to be totally responsible for the environment around them. (*Life Under Glass, The Inside Story of Biosphere 2* by Abigail Alling and Mark Nelson is the detailed account of the scientists' life.)

Interventions to save the project

The outside world had to intervene a few times: to get rid of an ant invasion, to pump in oxygen, to tend to a health emergency or two, to bring in forgotten necessities. The scientific team managed to last out the term.

Failures of the two year experiment - environment

Among Biosphere's problems that should have been obvious from the beginning: A great deal of time and money was expended in building an elaborate system of sprinklers into Bio2's ceiling. The system's designers intended it to simulate the respective amounts of rainfall for the various biomes. Alas, the water from the sprinklers condensed on the ceiling and fell on the desert, causing it to bloom. The desert biome, intended to be the arid dustbowl of Biosphere 2, is now as verdant and green as the rain forest.

The ocean biome, though billed as 'the largest man-made ocean in the world' was still too small for the huge number of fish the Bio2's biologists placed in it.

The 'ocean' was simply unable to sustain the oxygen levels necessary for such an enormous quantity of fish. The filtering system nearly choked on wave after wave of piscine carcasses. Hence, there are no fish in the "largest man-made ocean in the world."

Bizarre anomalous events occurred; all the species of bee died off due to the lack of UV light; swarms of so called crazy ants flourished killing off large sections of the insect population; oxygen concentrations dropped heavily. The closed environment of the Biosphere highlighted the effects that these factors play in the life cycle system; no bees meant that flowers remained unpollinated which, if unattended to, would eventually cause them to die out, decreasing photosynthesis and affecting levels of carbon dioxide in the atmosphere.

The idea of bringing in organically very rich soils that would produce a maximal agricultural output proved to be a most serious flaw which could not be corrected. The agricultural yield only produced about 80% of the consumed nutrition; the other 20% came from stored reserves, grown inside before the mission began. Harvests were much smaller than anticipated due to low irradiation levels (about 50% of the incident irradiation) inside the structure, which were caused by the glazed glass roof and by shading from the roof-mounting space frame structure. Also, high soil salinity and unforeseen pests such as broad mite, powdery mildew, cockroaches, aphids, crazy ants and many others led to significantly decreased harvests.

It was anticipated initially that the atmospheric composition would reach a steady state quickly and that comfortable living conditions for the inhabitants would emerge. The Gaia-theory of a self-regulating living system was the basis for composing the entire ecosystem inside the building, but self-regulation went in the wrong direction. The high proportion of organic material in all topsoils provided optimal conditions for soil micro-organisms, which released large amounts of CO₂ and consumed equivalent amounts of O₂. Within sixteen months, a third of the initial oxygen content was deprived from the

atmosphere. The only reason, why CO₂ did not rise to skyrocketing levels, but remained on a non-life-threatening concentration of around 4000 ppm was that the vast amount of uncured concrete within the structure was able to react with most of the emerged CO₂ to form calcium carbonate. The O₂ level was kept above 14% subsequently by pumping tons of liquid oxygen into the lung of the system.

Self-regulation did not only affect humans but also the rest of the fauna in unforeseen ways. Initially, more than 3000 plant and animal species were present in B2. Overall, only very few of the introduced animal species survived the experiment. In particular, the insect community changed in an unpredictable way. None of the originally introduced 11 ant species survived Mission 1; from the mid 1990s on, the insect community was dominated by a tramp ant, which entered the building during the construction phase and has thrived ever since, feeding on homopteran honeydew and on dead cockroaches, being the dominant nocturnal animals today. The enormous success of this ant species is based on its rapid, elaborate chemical communication. All pollinators went extinct due to predation by ants and cockroaches.

In the ocean biome, species surveys in 1992 and 1996 revealed a declining number of animal species (141 vs. 74), but an almost constant number of algae species (31 vs. 28). The number of plant species in the rainforest was reduced from 280 before Mission 1 to 170 after Mission 1 and to a relatively stable community of 70 species in 2004.

Failures of the two year experiment - humans

The work time spent for agriculture and food preparation was higher than expected (45%); the Biospherians worked an average of 66 h/week, spending less time than expected on research and data analysis (10%). Due to the high workload and the sparse nutrition (about 2000 kcal), the Biospherians lost about 20% of their body weight during Mission 1. Hunger and exhaustion were constantly present and were exacerbated by the low atmospheric oxygen content, which at times was comparable to the natural oxygen content at an elevation of around 5000 m.

Rushed to get the project underway after the long series of delays in building the facility, the first contingent of scientists moved into Bio2 before the concrete of the foundation had settled. The cement promptly absorbed large amounts of oxygen, oxygen that was vital for both the scientists and the organic balance of the whole project.

On leaving Biosphere2, the first wave of Biosphereans had lost an average of 20% of their body weight since they had first entered and spent much of their time bickering and arguing.

End of closed Biosphere system in 1996

In 1996, Columbia University offered a deal to the holding company that had recently assumed control of Biosphere2. Columbia proposed to come in and lend the project its name and vast resources in exchange for access to Bio2's research facilities. The new owners agreed, and sold it for only \$1 million. Columbia ran research programs out of Bio2 and used it to host College students on assorted semester-long internships in biology and ecology until it too pulled out in 2003.

It was a totally unsustainable programme about sustainability.

Analysis of the failure

Such fawning hype when the project was conceived would prove to be a liability for the project by attracting the cynics in the journalistic community. The most damaging attack was launched by Marc Cooper, a writer for the irreverent *Village Voice*. Cooper's scathing 1991 article, '*Take This Terrarium and Shove It*,' became the gold standard of Bio2 bashing. According to Cooper, '[T]he group that built, conceived, and directs the Biosphere project is not a group of high-tech researchers on the cutting edge of science but a clique of recycled theatre performers that evolved out of an authoritarian--and decidedly non-scientific--personality cult. In short, the Biospherians may be talking science, but what they are doing is more akin to well-financed science fiction.'

Other journalists soon picked up on Cooper's allegations of mismanagement, duplicity, fudging of science, and cultish activities, parroting his charges in their own articles and broadcasts. Many of these allegations were at least partially true: carbon dioxide scrubbers were secretly installed, supplies were smuggled in, and the management and crew were indeed long-time members of a decidedly non-mainstream group. In addition, former managers John Allen and Margaret Augustine took a defensive line, claiming that nothing

was amiss when the project was clearly not living up to its claims of self-sufficiency. The hermetically sealed dome of Bio2 provided little shelter from the ensuing torrent of bad press.

Why did the press suddenly turn so viciously upon a project that it had once literally praised to the moon? *The Economist* provided an apt explanation in 1992: 'The American media are now pelting Biosphere Two hard, perhaps because they are embarrassed by the uncritical praise they heaped on the project at first, praise which ignored the peculiar background of the project's organisers.'

Biosphere today

A tourist facility with a hotel and convention centre, and a 'world-class restaurant'.

"This is not Jurassic Park," Nancy explained. She was right. Jurassic Park had plants and animals in it. The Biosphere doesn't have a whole lot of either that aren't clinging to life. The trees are scraggly and brown. The ocean is filthy and contains no fish, only a rogue green turtle. In these inflationary times, you don't seem to get much for \$200 million: a glorified turtle tank with a few scrub pines, a fish-free ocean, and heaps of poor publicity.