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The Real Message from Biosphere 2

Last September, eight gaunt but triumphant Biospherians emerged through the airlock doors of Biosphere 2 after two years under public scrutiny and sealed glass (Alling & Nelson 1993). Their re-entry into Biosphere 1 (Earth) marked completion of the first in a century-long series of planned missions, the stated objectives of which are to explore scientific frontiers in ecotechnology (for better husbandry of the planet's resources and as a model for colonizing space) and in general to inspire the human spirit (Allen 1991). The latter goal already may have been achieved. Aficionados see the endeavor as audacious and visionary—"the most exciting venture undertaken in the U.S. since President Kennedy launched us towards the moon" (see the previous reference). And, unlike NASA's lunar mission, this \$150 million program was launched entirely from private venture capital!

For those who don't already know, Biosphere 2 is a futuristic glass and steel "greenhouse" nestled in Arizona's Sonoran desert, about 30 miles north of Tucson. Engineered to be a self-sustaining mesocosm, almost completely sealed off from atmospheric or other material exchange with the outside world, the graceful three-acre enclosure houses nearly 4000 introduced species of plants and animals in a Garden-of-Eden-like setting of tropical rainforest, marsh, desert, savannah, streams, agricultural area, and even a miniature ocean complete with coral reef. Biosphere 2 receives energy as sunlight and as electricity (from an adjacent natural-gas power plant) that drives a vast "technosphere" of pumps, sensors, scrubbers, air-cooling systems, and other electronic and engineering wizardry designed to keep the environmental systems within boundaries suitable for life.

I recently returned from a second visit to Biosphere 2 (as an independent researcher), and once again my mind is aspin with ambivalent impressions. There is the commercial side—on adjacent grounds you can purchase biomeburgers, habitat hotdogs, and planetary pizzas, or browse gift shops and bookstores. There is the mystical side, exemplified by the many evocative sculptures with names of Indian Gods fashioned of stainless steel salvaged from the Los Alamos atomic bomb project. There is the educational side, where thought-provoking films and tours explain ecosystem functions and their relevance to the design of space modules.

There are the many ecotechnological paradoxes of Biosphere 2 itself, where earthy smells of compost and forest contrast with the electronic sterility of the computer control room and where the Biospherians' simple agrarian lifestyle seems in opposition to their sophisticated telecommunications with the international press. And then there is the scientific side, a focus of much controversy and media attention. Whether sound basic research eventually can find a good home in Biosphere 2 remains to be seen (Watson 1993), but I am optimistic.

Overriding scientific lessons from Biosphere 2 already may be available. To many of us, healthy ecosystems and biodiversity have inestimable aesthetic value, but such philosophical orientations are difficult to translate into the kinds of economic terms that carry weight with business or industrial interests. Some far-thinking economists have sought to attach dollar values to natural ecosystems by virtue of the fundamental life-support services rendered (e.g., atmospheric regulation by rainforests and oceans, water purification by marshes, groundwater storage by aquifers, soil generation and maintenance by decomposers), but such attempts are almost hopelessly complicated by the vast range of spatial and temporal scales over which the monetary valuations might be tabulated. However, thanks to the controlled experiment of Biosphere 2 we now have a more explicit ledger.

The cost of the man-made technosphere that (marginally) regulated life-support systems for eight Biospherians over two years was about \$150 million, or \$9,000,000 per person per year. These services are provided to the rest of us more-or-less cost-free by natural processes, but if we were being charged, the total invoice for all Earthospherians would come to an astronomical three quintillion dollars for the current generation alone! The sad irony is that, as a species, we blithely take these ecosystem services for granted, acting as though we can endlessly befoul and overpopulate our planet.

During their two years of voluntary incarceration the Biospherians became acutely aware of their intimate connections with, and complete dependence upon, the fragile ecosystems within Biosphere 2: "It seemed as though we had touched every aspect of our world; we interacted with molecules and with trees, we knew our environment's boundaries and its subtleties" (Alling & Nelson 1993). The Biospherians would never have tolerated in their small household the kinds of practices that are so widespread in our broader world—massive deforestation, water and atmospheric pollution, the dumping of toxic chemicals, or overexploitation of renewable and nonrenewable resources. Nor would human population growth within Biosphere 2 have been tolerable—both oxygen and food supplies already were stretched to the very limits, to the point where supplemental oxygen had to be injected at the end of year one, and the scanty food stores had to be placed under lock-and-key to prevent recurring incidences of theft by the hungry Biospherians (see previous reference). Clearly, the facility was close to if not well beyond human carrying capacity, even in the short term, and even with massive energy subsidies from the outside.

Exactly how many people the earth can hold remains uncertain (Cohen 1992), but many signs indicate that we are rapidly approaching achievable limits. Indeed, if carrying capacity is defined (as it often is) as the maximum population that can be supported without degrading the environment, then the earth's carrying capacity already has been exceeded. Ozone depletion and atmospheric pollution are global concerns, as are losses of ground-water supplies and usable surface-waters, soils, fossil fuels, and species. Massive hunger, starvation, and conflicts

over limited resources are recurring themes in many regions of the world. Current population densities over vast areas are not grossly different from those in the crowded Biosphere 2. For example, across the nearly four million square miles of Europe, densities already *average* nearly 0.3 people per acre, more than 1/10th the density of Biospherians inside Biosphere 2. Astonishingly, our species currently shows a net increase of more than 10,000 people every hour, a quarter million people each day (Meffe et al. 1993), and within our children's lifetimes the global population is projected by the United Nations to quadruple under current fertility rates. How much farther the earth's life support systems can be pushed remains to be seen, but all of us are the unwitting guinea pigs in this reckless and utterly pointless experiment with global carrying capacity. Unlike the inhabitants of Biosphere 2, we have no outside source of rescue or escape. We can only save ourselves, through immediate and humane efforts at population control.

Herein lies the real message from Biosphere 2. It may be fun and even inspirational to dream of colonizing other planets, but the harsh reality is that we have but one home, and it is getting untenably crowded. Whether based on ethical or purely utilitarian considerations, human societies must learn to properly value our Earth, and quickly. Like the astronauts' views from space, Biosphere 2 should give us a novel perspective and renewed appreciation of Biosphere 1.

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