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Book review

Mark Nelson. *Pushing our Limits: Insights from Biosphere 2*. Tucson, AZ: University of Arizona Press. 2018. 328 pages. Paperback & ebook, ISBN: 9780816537327. USD 22.95.

Pushing our Limits: Insights from Biosphere 2

Anybody who lived in the US in the early 1990s would remember the television coverage of "Biosphere 2"—a prototype Mars colony on earth built in the Arizona desert. The lingering memories are of media coverage that focused on the failures and bordered on the salacious. Four women and four men entered a glass and steel frame building that "included small chunks of Earth's biodiversity; bonsai rainforest, tropical grassland (savanna), desert, mangrove marsh, and coral reef ocean" in September 1991. They began a two-year "closure" experiment to study how global ecological processes work in a sealed environment. Twenty five years after the event, one of the 8 volunteers—Mark Nelson has written a book about it. With a fascinating account of the challenges faced in maintaining quality of the air and water inside, the author makes the case that many of the lasting lessons of the experiment may be applicable right here on Earth where climate change and environmental pollution have assumed centre stage in a way not foreseen at the time of the closure of Biosphere 2.

With funding from Ed Bass—a Texan and heir to a fortune who came under his influence—the big dreaming leader Paul Allen set out to create a closed functional replica of the earth (Biosphere 1). The Soviets were the early pioneers in such systems, with Bios-3 used in the early 1970s, where 3 people could spend up to 6 months (although not as a completely self contained system). Recycling waste and keeping the air and water clean is as much a challenge in today's Earth as it was in these closed systems. Building on the prior experience of ecologists engineering mesocosms, the Biospherians hoped to "reintroduce ecological approaches to the challenge of space life support".

Almost immediately after the closure of Biosphere 2, carbon dioxide (CO_2) concentrations inside went up—exceeding 1500 ppm within days. Much of this increase had to do with the ratios of biomass-carbon to atmospheric carbon (100:1 in Biosphere 2 compared to 1:1 on Earth) and soil carbon to atmospheric carbon (5000:1 in Biosphere 2 compared to 2:1 on Earth). These carbon reservoirs more readily transfer to and from the atmosphere than does the largest carbon reservoir—the minerals in the solid Earth. The solid earth exchanges carbon with the atmosphere through weathering and tectonic activity—slow processes that act on geologic time-scales. If such large reservoirs give up their carbon easily, the atmosphere would be swamped with CO_2. The carbon in the atmosphere of Biosphere 2 stayed for just 2-4 days (cycling time) as compared to 3 years in the Earth's atmosphere.

Such a high CO_2 level by itself isn't harmful to humans or plants. The CO_2 acts as a fertilizer, and plants grow more vigorously, provided levels of other nutrients and temperatures are conducive. The controlled temperatures inside Biosphere 2 and the care taken to ensure other nutrients were not depleted meant that vegetation cycled carbon more vigorously than in the real biosphere. The seasonality of growing cycles (primarily dictated by sunlight availability) meant that the biomass produced in the growing months had to be stored in such a way as to not contribute to the higher CO_2 levels in Biosphere 2. Six months after the closure, the oxygen levels inside Biosphere 2 were markedly lower than when the closure experiment started, and continued to decline. But the increased CO_2 levels were not sufficient to account for how the oxygen levels had come down. One of the most interesting passages in the book describes how this decrease in oxygen is traced to soil microbes and the lack of a corresponding increase in CO_2 to exposed concrete pillars. The continued drop in oxygen concentrations (down to 14% or the equivalent of being at an altitude of 4.5 km above msl) caused physiological problems for the inhabitants and eventually led to artificially pumping in oxygen into Biosphere 2. This essentially marked the end of what was an ambitious experiment.

As one watches climate change unfold from increasing CO_2 concentrations, the lingering scientific questions include the carbon cycle and its feedbacks on the climate. The role of soil carbon and how soil microbes interact with the atmosphere and react to increased temperatures are particularly poorly understood. But answering these questions is critical to the success of any measures to regulate CO_2 concentrations in the atmosphere. But how does one develop the necessary scientific understanding when we on Earth have been running what is essentially a "live experiment" with multiple changes made at the same time and no control scenario for comparison. This essentially means that there will always be questions about what causes the changes one observes, and making definitive conclusions about the phenomena we observe becomes difficult. Biosphere 2 was another such live experiment plagued by the same issues of inconclusive evidence. Would one design a scientific experiment that way? Clearly there are situations in drug trials and public health interventions where adjustments are made to experimental protocols on the fly to ensure that subjects are not harmed, but statisticians are still figuring out how one draws conclusions from such experiments. The author makes a rather unconvincing case for

the utility of such experiments to learn anything about how complex systems behave. The repurposing of Biosphere 2's messages for climate change comes across as preachy, while leaving the reader hanging agonizingly close to understanding the scientific findings. One really has to go into the notes and references to actually get those details, and fortunately there are enough to keep the interested reader engaged.

The tension between a controlled scientific experiment and a live one appears to have been the cause of much of the interpersonal problems that arose during the 2-year closure. Much of the book is spent on hinting at the problems that arise from staying cooped up for 2 years, but never makes clear what actually happened. The reader is left with the feeling that there are unresolved tensions even after 25 years. Can these be traced back to the origins of the idea of Biosphere 2? Was it conceived as a science experiment or was it a cool idea to show the world how humans can manage everything even in a small controlled setting. Perhaps it was the publicity, lofty promises, and bad press that set this whole endeavor on a tragic path. This book ultimately is one about the conflicts inside Biosphere 2.

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