Species packing into Biosphere 2

by Tony Burgess

Dr. Tony Burgess in the Biosphere 2 desert biome in 1993. The desert began transforming into chaparral scrubland after receiving extra rain for more than a year to increase carbon dioxide uptake.

In 1991, Biosphere 2 was launched in Oracle, Arizona. It is a 3-acre structure built to enclose seven biomes or habitats: rainforest, coral reef, mangrove wetlands, savanna grassland, fog desert, an agricultural system, and living space for eight humans who called themselves biospherians. It remains the largest closed system ever created.

Biosphere 2 was originally designed to discover how closed ecological systems could maintain human life in outer space. The first attempt to live for two years within these hopefully self-sustaining systems went awry when food and oxygen became scarce. The second attempt was aborted after a few months by a management dispute.

Earth, too, has experienced changes in atmospheric composition and climate in its past. Most shifts have been slow enough to allow plants and animals time to adapt and evolve as they generally became more taxonomically diverse. But five times in the past 450 million years, more than 75% of known species disappeared from the fossil record when climates changed too quickly.

Many scientists agree we are sliding into the sixth mass extinction, driven by human activities such as logging, farming, overharvesting, and polluting, but also by a climate rapidly warming in response to greenhouse gas emissions. The designers of Biosphere 2 did not envision their grand experiment might have more relevance to our warming Earth than to colonizing space.

I was an ecological designer of the Biosphere 2 desert and savannah biomes, and later helped manage them. Now I live in Homer.

The biomes inside Biosphere 2 were to evolve within nearly total material closure for 100 years, with occasional modifications, and humans would inhabit almost continuously as involved observers, rotating crews every two years. A century is a long time for humans; however, it's only enough time to grow a young forest or form a weakly developed soil.

Why did we design so many biomes into Biosphere 2? More opportunities to learn. All we knew for certain was that the only known biosphere, Earth, has many biomes which interact in creating air and water chemistries that foster life. Mostly powered by sunlight, our planetary biosphere consumes incoming energy to create complex, evolving, carbon-based life, diversifying in interacting ecosystems that continuously recycle essential nutrients.

We didn't know which biomes would be best, and there were few clues. What became clear was that an agricultural biome alone would not be adequate—current agricultural technology causes rapid fluxes of carbon dioxide that destabilizes atmospheric chemistry. For example, every time the soil was tilled, a large burst of carbon dioxide was released into the air.

The question that challenged us was how to create a biosphere that evolved as quickly as possible, while sustaining as much diversity as possible. Fortunately, a theory of island biogeography offered hints about maximizing species richness in closed ecosystems. The most species-rich islands tend to be those that had once been connected to continents rather than islands that arose from volcanoes or coral reefs. After becoming isolated by rising sea level, these continental fragments (now islands) with higher species richness adjust to the more limited resources of an island.

Similarly, we assumed well-adapted species would accumulate more rapidly in Biosphere 2 if we overpacked our small biomes with lots of plants and animals, an idea we called "species packing." As the famous ecologist Howard Odum advised us, "shovel the species in, and let extinction sort it out."

Choosing which species to colonize each biome proved controversial. Each biome had different designers with differing ecological ideas. For example, the mangrove biome was constructed by transporting large, intact chunks of soil with growing mangroves from the Florida coast into Biosphere 2. In contrast, I used a synthetic approach for the humid desert biome, populating it with plants from several coastal deserts in Baja California, Israel, Namibia and Chile.

Microbial communities are the critical foundation for a biosphere, yet they are the least understood. In the 1980s when we were designing Biosphere 2, technology for assessing microbes was too crude for detailed inventories. However, we were certain that if there were diverse environments inside Biosphere 2, inoculated with soils and waters from diverse places, there would soon be well-adapted microbial communities to recycle nutrients and stabilize air and water chemistry. A similar process occurs in aquariums and aquaponics systems, when their ecosystem "pops" into a state that can process fish waste into plant nutrients.

Establishing adaptable populations of plants and animals posed greater challenges. Space and light energy were limited in our 'island', hence the number of individual organisms had to be limited. However, more individuals of each species meant fewer species could be included. So we developed a compromise design strategy. We emphasized species richness in plants and smaller invertebrates such as roaches and ants. In contrast, we included only a few vertebrate species such as coqui frogs and Solomon Island skinks, but we stocked enough individuals to ensure breeding populations.

Management changes cancelled the goal of a century of observation and evolution. Yet even during the few years of closure, community adaption was evident. During the first closed mission, condensation on the glass dripped extra moisture into the soil, and rainfall in the desert biome was substantially increased to offset oxygen loss. Within two years, the desert vegetation structure changed from open shrubland to denser chaparral. Many desert plant species died, but those favored by the wetter climate allowed a rapid transition to better adapted vegetation. Surveys discovered two species new to science, a protozoan and a soil nematode, indicating that novel communities were forming rapidly from diverse inoculations. The invertebrate food web began to organize with crazy ants (Paratrechina) as keystone predators, similar to islands where this ant has been introduced.

How might such concepts apply in Alaska where climate is warming at twice the rate of the Lower 48? Unlike previous mass extinctions, powerful technologies currently alter the land and its ecology. New species are pouring in with global trade, tourism, and gardeners' desires for ornamental plants. Some of these species, including earthworms, pasture grasses, and agricultural weeds, have become invasive in Alaska. Interactions among economic globalization, technological evolution, cultural evolution, climate change and human population growth are certain to cause major, disruptive changes in Alaska's ecology.

Might Alaskans want to learn how to assist ecological adaptation that could sustain healthy environments in boreal and arctic regions? The basic questions are the same as those that confronted us in designing Biosphere 2.

Dr. Tony Burgess, now retired, continues to grow many different plants on his small farm outside of Homer. Find more Refuge Notebook articles (1999–present) at https://www.fws.gov/refuge/Kenai/community/refuge_notebook.html.