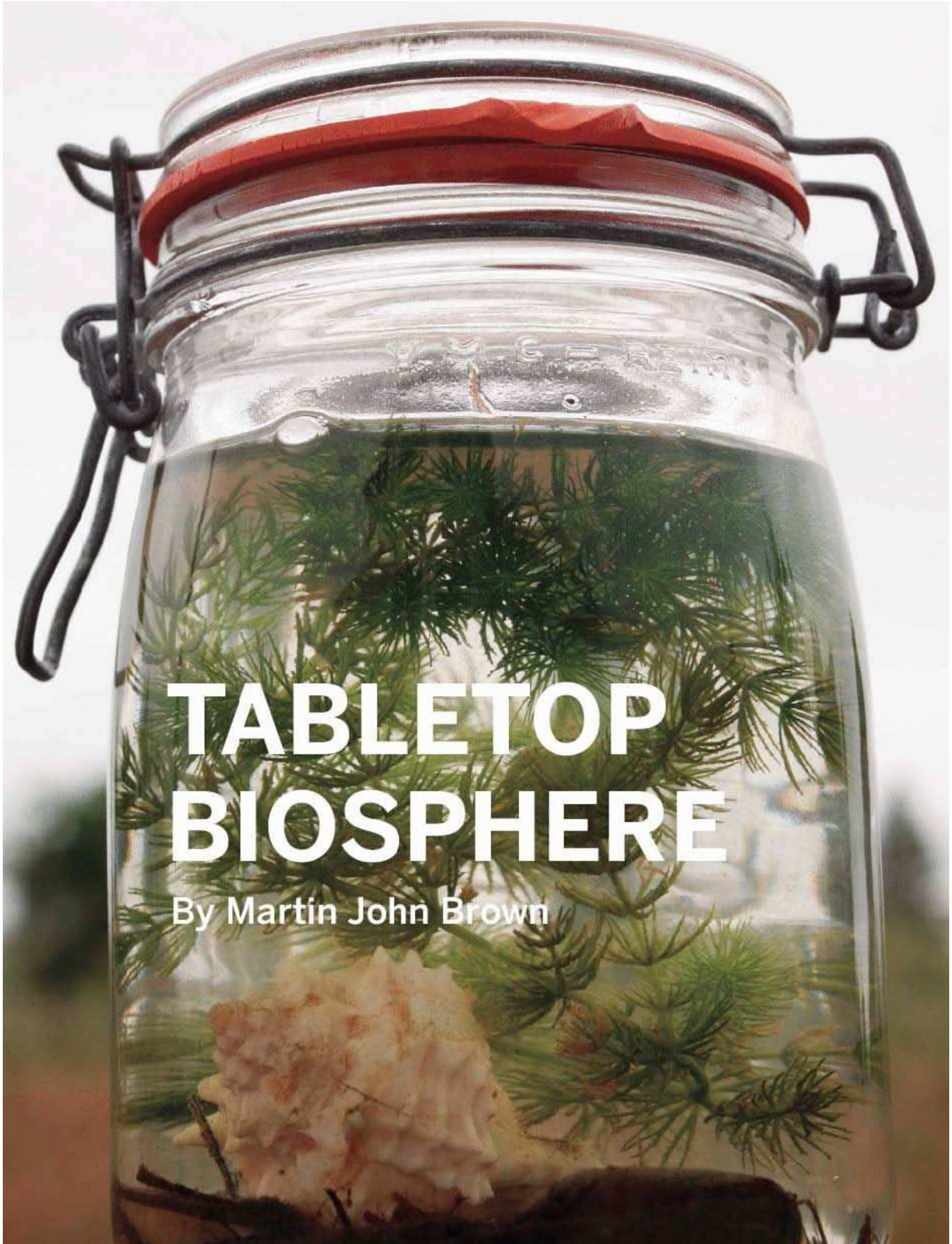

TABLETOP BIOSPHERE

By Martin John Brown

ECOSYSTEMS ENGINEERING

The Tabletop Shrimp Support Module (TSSM) is a fun demonstration of the ecological cycles that keep us alive — and an enticement to muse on everything from godhood to space colonization.

When my 7th grade vocational aptitude test came back stamped "Forester" instead of "Astronaut," I knew the test-makers had screwed up. Sure, I liked sitting in streams, and peering down those creepy holes by the roots of old trees. But I also knew that someday the whole frickin' park would be flying through space. Hadn't anyone else seen *Battlestar Galactica*?

Now we know that space colonists are just as likely to be muddy ecologists as hotshot flyboys — the kind of people who assemble ecosystems instead of engines. Today's pack-it-in, pack-it-out life support is impractical for long, manned missions, but in the future, regenerative systems could provide years' worth of food, air, and water while processing human waste. It's recycling and reuse on a radical scale, light years beyond anything pitched by those hairy guys down at the co-op.

Here's a mini version of this dream, a sealed system that supplies a freshwater shrimp "econaut" with food, oxygen, and waste processing for a desktop journey of 3 months or more.

Photography by Sam Murphy

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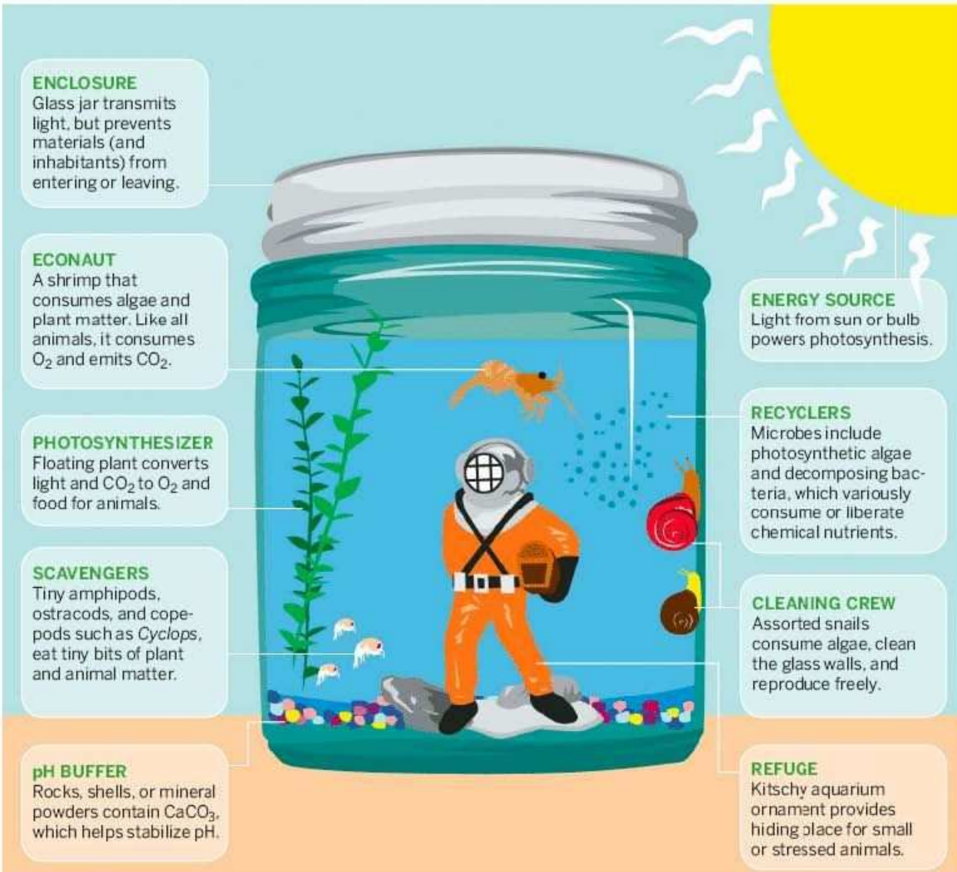
Martin John Brown (**martinjohnbrown.net**) is writing a book about isolation, biological and otherwise. He really likes the blog **bottleworld.net**.

TABLETOP SHRIMP SUPPORT MODULE: HOW IT WORKS



On Spaceship Earth, little goes in or out except light and heat, and all organisms live off each other's waste, whether it's oxygen from plants or feces from animals. Our world is bottled up.

Ecologists have often scaled down these processes, creating sealed aquariums for research. Meanwhile, space scientists have searched for organism and machine combinations that could cooperate to support humans in a space colony.

The TSSM's basic principles come from ecologist H.T. Odum, but many details derive from the Autonomous Biological System (ABS), a sealed aquarium invented by Jane Poynter, which has returned healthy from extended trips on the space shuttle and the Mir and ISS space stations.

The Cast of Waterworld

In our TSSM, the "econaut" we imagine ourselves in the place of is a shrimp. We encourage photosynthesis and waste processing with abundant light and vascular plants, and we limit oxygen demand by constraining animal biomass and algae-fertilizing nitrate and phosphate. Protection against chemical spikes comes from pH buffers.

Illustration by Dustin Hostetler/UPSO

SET UP.

MATERIALS

[A] 1-quart glass canning jar Don't use plastic: it may bleed air.

[B] Clear bottles or plastic containers for sampling and a "holding tank"

[C] Tap water

[D] Small river rocks just enough to cover the jar bottom. Rocks piled too thick let muck and algae build up where snails and shrimp cannot eat them.

FROM AN AQUARIUM STORE

[E] Tap-water dechlorinator

[F] Aquarium ornament(s) or other glass or ceramic obstacle(s) Seashells also are nice, and supply extra calcium carbonate.

[G] Fine fishnet or kitchen strainer

[H] Freshwater minerals such as "Kent Freshwater" or "cichlid salts" These are essential trace nutrients.

[I] Amano shrimp (1) (***Caridina multidentata***) an algae-eater with a reputation for tolerating high pH

[J] Snails (4) of assorted species smaller than 1cm each.

[K] 8 stem inches of hornwort (***Ceratophyllum demersum***)

[L] 2"×2" piece of duckweed (***Lemna***). You can also collect this from a local pond.

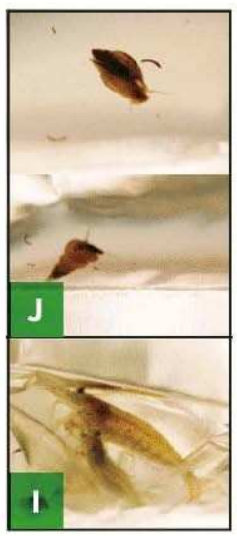
[NOT SHOWN]
1Tbsp powdered calcium carbonate This is your primary pH buffer.

FROM A LOCAL POND

Assorted amphipods (2–8) These are tiny crustaceans; try to collect 8, but you can use fewer.

1 or 2Tbsp pond sludge hopefully containing copepods and ostracods (even tinier crustaceans), bacteria, microalgae, etc.

NOTE: Aquarium fish, shrimps, and snails may be invasive and destructive if released into the environment, so boil or freeze them after the experiment. Or keep them living in an aquarium environment.



Materials and shrimp photography by Sam Murphy; snail photography by Martin John Brown; hornwort photo by Christian Fischer

CREATE YOUR BIOSPHERE

START **Time: A Day Complexity: Easy**

1. GATHER THE AQUARIUM SUPPLIES

1a. Visit an aquarium store for the materials listed on the previous page. While you're there, ask them how to dechlorinate local tap water for aquarium use.

NOTE: The store staff might not believe that your Tabletop Shrimp Support Module will work. Make nice anyway.

1b. At home, dump your shrimp, snails, hornwort, duckweed, and the water they came in into an open "holding tank." I use a plastic Tupperware or yogurt container. Add some dechlorinated tap water to keep everything comfortable (alive).

2. COLLECT THE POND LIFE

Go to a local pond. Spring and summer are best. Bring a net or bottle (or other container), and visit during late afternoon. That's when the pH is higher, like that of your TSSM.

2a. Find a good, shallow area of the pond to collect your goodies. If you see duckweed, water lilies, or other vascular plants, try near there. I've done well in areas with a mixture of substrates, like sand, rock, and decaying wood.

Aquarium store and pond photos by Martin John Brown

2b. Drag your bottle or net through mud, rocks, and half-submerged plants. Examine your take for shrimp-like creatures 1mm–10mm long. These are probably amphipods; collect up to 8 of these if you can. You need to look aggressively, getting into the muck and shaking bits of plant away. Then collect 1 or 2Tbsp of pond sludge from the pond bottom, which should contain some nearly microscopic copepods and ostracods. Back home, dump your pond samples and sludge into the holding tank.

3. BOTTLE IT UP

3a. In a new container, whip up a gallon of NPFW (nitrate-poor fresh water). This is tap water, dechlorinated and supplemented with your freshwater mineral mix (follow package directions).

3b. Thoroughly rinse your "fixtures" — quart canning jar, ornaments, rocks, etc. — with NPFW.

NOTE: Waters from the aquarium store and pond are probably loaded with algae and algae-supporting nitrates, which will lead to algae takeover. Diluting with NPFW helps prevent this.

Photography by Sam Murphy

3c. Fill your jar halfway with NPFW, and transfer all the ingredients to the jar, except for calcium carbonate powder, if used: shrimp, snails, hornwort, duckweed, amphipods, sludge, ornaments, rocks, seashells. Use the quantities listed. Do not put in extra animals or sludge, or otherwise mimic a traditional aquarium. What makes this system work is its sparseness.

3d. Fill the remaining volume of the canning jar with NPFW, leaving 1" or 2" of airspace at the top. If you have calcium carbonate, add it last, and note that it will cloud the water for hours.

3e. Say a little prayer as you tighten the cap on the jar.

3f. Your biosphere is complete! Place it in a spot with a fairly consistent temperature (70–80°F) and 12–16 daily hours of moderate light. Standard room lighting is too dim, and direct sun is too much. A bright north window or a 50W bulb a few feet away are both good, but watch the temperature.

FINISH X

NOW GO USE IT »

USE IT.

ENJOY YOUR BIOSPHERE

Maintaining the TSSM is a joy. There's no feeding or fiddling with parameters. Just observe and philosophize. Get enchanted with your econaut shrimp, casting its antennae in slow looping rhythms. Watch the snails cruise the glass like silent Sumo wrestlers on night patrol. Zoom in on the tiny creatures oozing out of the muck. They are the bottom of the food chain, the disassemblers of the dead.

There's never been another world like this one. In a way, you're God! Which might bring on some curious emotions if something goes awry. Multispecies assemblages like the TSSM are never 100% reliable. Your econaut might die mysteriously. Or you might observe signs of stress: shrimp that molt and then shrink instead of grow, or carnivory among normally vegetarian shrimp or snails. Hard questions arise. Was it right to start this world? Will you intervene, or abandon your creations to a sealed fate?

Life inside such tight ecological loops is rarely a cakewalk, and this begs some questions. Does closed-system sustainability simply emerge as you scale things up? Or is there something about the Earth and its milieu of flux on flux that we've failed to understand so far? Might our increasingly crowded planet, with a rising rate of extinctions, start resembling a laboratory microcosm? And for those with sci-fi dreams, could living on Mars be little more than desperate farming?

But if ecosystems engineering makes progress, we have hope. Mark Kliss, chief of the Bioengineering Branch at NASA's Ames Research Center, envisions extraterrestrial life support systems that provide a high quality of life, with a big contribution from automation. Machines and software could monitor conditions and energy inputs, nudging ecological feedback loops away from mutual parasitism and into productive symbiosis.

It's a vision our environmental movement might consider. The thing that finally allows people to live in balance with nature might be technology, the force that once seemed most opposed to it.

Amano shrimp chills upside down.

Snail grazes on algae.

Snail-on-hornwort action.

Photograph of snail eating algae by BC Anna; all others by Martin John Brown

"Econaut" Jane Poynter working within Biosphere 2.

Beyond Spaceship Earth

At least 5kg of food, water, and oxygen must be lifted into space for every person-day spent on the International Space Station, relates NASA's Mark Kliss. For human habitation on the Moon, Mars, or elsewhere — stays of hundreds or thousands of days — that adds up to an unworkable ball and chain.

That's why Kliss and others are trying to replicate the closed-system sustainability of Spaceship Earth. Academics have long built "closed ecosystem" models for streams or lakes to investigate subjects like carbon cycling and population dynamics. For potential space travel, the conditions are far more constrained. Species may be mixed in ways never seen in nature, but must include the target species, humans.

American and Russian space scientists have been working on the problem since the 1960s. Early Russian tests were brutally simple: one guy climbed into a cask with little more than a light and a bucket of photosynthetic algae, to stumble out 24 hours later, alive and stinking. Progress has been slow, and no bioregenerative systems have yet been used in space for human life support.

Research has followed two paths. Space agencies have focused on highly engineered systems that include just a few well-understood species and fully account for their chemical products and needs.

Projects like Biosphere 2 (and the TSSM project here), however, take a more top-down approach. Thousands of species were imported to Biosphere 2's fantastic glass structure in the Arizona desert, and assembled into new forests, farms, and "oceans." By the time eight jump-suited "econauts" were sealed in, in 1991, it was a publicity juggernaut.

Over the next two years — the duration of a Mars expedition — the econauts met the recycling challenge, surviving very largely on regenerated air, food, and water. But their elaborate menagerie suffered a hard shakeout. Oxygen declined to dangerously low levels, and food became scarce. Extinctions were rampant and, critically, included all the pollinating species.

Life in Biosphere 2, that questing ecological utopia, wasn't sustainable. When ecosystems are sealed off, it's *Escape from New York*. Systems must balance locally, and an ecological shakeout ensues. The community that emerges may be strange and new, or as dismal as pond scum. Even with our TSSM, you can follow the same recipe to bottle up more than one tabletop biosphere, and things will evolve in different directions.

As Kliss philosophizes, closed ecosystems tread a fine line between symbiosis and mutual parasitism. Will the inhabitants help each other survive, or eat each other alive?

+ Resources at makezine.com/10/biosphere

Photograph courtesy of Roy L. Walford Living Trust