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Review article

Group dynamics challenges: Insights from Biosphere 2 experiments

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ABSTRACT

Successfully managing group dynamics of small, physically isolated groups is vital for long duration space exploration/habitation and for terrestrial CELSS (Controlled Environmental Life Support System) facilities with human participants. Biosphere 2 had important differences and shares some key commonalities with both Antarctic and space environments. There were a multitude of stress factors during the first two year closure experiment as well as mitigating factors. A helpful tool used at Biosphere 2 was the work of W.R. Bion who identified two competing modalities of behavior in small groups. Task-oriented groups are governed by conscious acceptance of goals, reality-thinking in relation to time and resources, and intelligent management of challenges. The opposing unconscious mode, the "basic-assumption" ("group animal") group, manifests through Dependency/Kill the Leader, Fight/Flight and Pairing. These unconscious dynamics undermine and can defeat the task group's goal. The biospherians experienced some dynamics seen in other isolated teams: factions developing reflecting personal chemistry and disagreements on overall mission procedures. These conflicts were exacerbated by external power struggles which enlisted support of those inside. Nevertheless, the crew evolved a coherent, creative life style to deal with some of the deprivations of isolation. The experience of the first two year closure of Biosphere 2 vividly illustrates both vicissitudes and management of group dynamics. The crew overrode inevitable frictions to creatively manage both operational and research demands and opportunities of the facility, thus staying 'on task' in Bion's group dynamics terminology. The understanding that Biosphere 2 was their life support system may also have helped the mission to succeed. Insights from the Biosphere 2 experience can help space and remote missions cope successfully with the inherent challenges of small, isolated crews.

1. Introduction

The Biosphere 2 closed ecological system facility in Arizona created a new kind of laboratory for study of global ecology and as a prototype for space life support environments (Nelson et al., 1993) and biospheres. An ambitious project – unprecedented in scale, interdependency of life systems, complexity and duration of its intended experimental life, Biosphere 2 was designed for a series of closures taking place over a one-hundred year time period, researching ecological self-organization and integrating humans, technology and agriculture in an overall small scale biospheric system.

Two closure experiments were completed with human inhabitants. The first closure had a crew of eight for two years, 1991–1993, and a second closure experiment had a crew of seven in 1994 for 6.5 months. Some of the human factors and group dynamics from the first closure which have not been previously published can be relevant for future space exploration and habitation.

High amongst the many challenges for participants of extended duration space exploration and habitation are coping with isolation and with group dynamics. Initially, such groups will be few in number, separated from Earth and living in small spaces such as spacecraft, orbiting space stations or habitations on moons or planets. Considerable research has been conducted with space crews, simulated space missions, and comparisons with broadly similar environments, e.g. personnel in Antarctic bases, on remote expeditions and in submarines (Harrison et al., 1991; Finney and Jones, 1985; Stuster, 1996). But significant concerns remain, given potential for group conflict and psychological disturbances in any human group, especially those in pioneering circumstances isolated from existing society. In a summary of psychological, social and medical findings from 40+ years of Antarctic over-wintering crews, characteristic problems resulting from Isolation, Confinement and

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Fig. 1. Aerial photograph of the Biosphere 2 facility, showing rainforest, savannah/ocean/marsh to desert (top section of glass space frame), human habitat and agriculture (barrel vaulted structure middle right), two variable volume "lungs" (white domes) and external energy center (bottom right). The research and development complex is at the top of the photo (photo by Gill C. Kenny).

Fig. 2. The eight biospherians, photographed shortly before closure. From left: Mark van Thillo, Roy Walford, Abigail Alling, Linda Leigh, Jane Poynter, Sally Silverstone, Mark Nelson and Taber MacCallum (photo by D.P. Snyder).

Environment (ICE) were depression, irritability, insomnia and cognitive impairment (Palinkas, 2002).

2. Unique characteristics of the Biosphere 2 environment

Antarctic over-wintering and space exploration teams live in indoor environments, in the midst of an extremely cold, barren environment hostile to humans. Space expeditions deal with microgravity with no life support available outside their space cabins and spacesuits. In both environments, there are few green plants apart from small greenhouses in the Antarctic and in tiny space experimental plant-growing equipment. While Antarctic researchers go outside for scientific exploration or maintenance tasks, the severity of the environment necessitates careful planning and contingency safety measures.

Biosphere 2 contained a moist, semi-tropical environment with an abundance and diversity of living systems, with areas modeled on major Earth biomes – from rainforest to desert to coral reef ocean and farm. Architecture incorporated classic forms like stepped pyramids, barrel vaults, geodesic domes and an intricate mosaic of spaceframes tightly sealed to make the structure exchange less than 10% of its air annually (Dempster, 2009), an unprecedented degree of material closure in a closed ecological system facility. The term "closed ecological system" refers to its approximation to material closure which requires methods for regenerating air, water and producing food. Such systems are energetically open (for energy inputs for light, electricity, heating, cooling and for discharge of excess heat) and informationally open.

Although there was concern about potential toxic gas or water contaminants developing (a decline in atmospheric oxygen occurred during the first two year experiment and nitrous oxide increased), its crew of biospherians enjoyed a warm, green environment with clean air and water and freshly harvested food, offering strong parallels to "normal" environmental conditions. The facility was located in the northern Sonoran desert and majestic mountain vistas could be viewed from within the structure. It was spacious, with a total footprint of some 1.25 hectares and internal heights over 20 meters (Dempster, 1999) (Fig. 1).

3. Shared features with space applications

Biosphere 2 shared with these other settings the factors that the crews are relatively small (though Antarctic overwintering crews are somewhat larger and some space crews fewer in number) and physically isolated (Fig. 2). Mission rules in Biosphere 2 were that the participants would stay inside the facility for its two-year duration unless a medical emergency couldn't be handled inside or a health/safety issue with the system necessitated departure (e.g. a fire or trace gas buildup in the atmosphere, overheating, etc.). Like Antarctic and space station crews, there could be periodic resupply through the Biosphere 2 airlocks though it was only used during the second year of the closure experiment for sending out scientific samples and importing scientific equipment.

4. Stress factors

Stress factors of the two year closure experiment in Biosphere 2 included the following:

1. **Adjustment time**. Because closed ecological systems will differ in small or large degree from planet Earth – from accelerated biogeochemical cycling times, mosaic of living and man-made habitat, differing atmosphere, water and food – there will be a period of adjustment of each crew member to their new environment (Alling et al., 2002).

2. **Food production and caloric limitations**. Producing all the food required on a small intensively farmed area involved hard physical work and limitations on types of food available for meals. Recreational substances, e.g. alcoholic beverages and coffee, were restricted to what could be brewed inside or harvested from coffee trees. El Niño Southern Oscillation (a climatic condition resulting from warm Pacific waters disrupts normal weather patterns and results in more cloud cover and rain in the US southwest where Biosphere 2 was located) during both fall/winter seasons and a learning curve to maximize food production in Biosphere 2's environment, resulted in a caloric-restricted but nutrient-dense diet. The diet the first six months of operation was limited though very healthy, with 1800–2100 kcal per day per person. The American and European first crew however was unused to being responsible for their food source as "subsistence farmers" and dealing with hunger (Silverstone and Nelson, 1996; Alling and Nelson, 1993). During the second year, calories rose as farming skills and creativity increased, averaging 2400 kcal. This diet serendipitously was consistent with crew member and medical researcher Roy Walford's experimental findings on low-calorie dietary intake for maximum life extension (Walford et al., 1992). During the first Biosphere 2 closure experiment, 83% of food was produced from crops grown during this timeframe, with the rest coming from crops grown in the facility prior to closure and seed stock. During the second closure experiment in 1994, 100% of the diet was grown inside (Marino et al., 1999).

3. **Work load**. Running the entire biospheric system, from managing the biomes, maintaining equipment, farming and processing food (25% of the overall work load), analytic lab and medical work, rotating cooking duties which meant preparing three meals once every eight days, doing scientific research projects and responding to media and outside questions required, on average, 8–10 hours daily per person over a 5½ day work week (Allen and Nelson, 1999) (Fig. 3).

4. **Us–them syndrome**. Like many space and other explorers and researchers, there were times when the biospherians felt that