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Review article

Group dynamics challenges: Insights from Biosphere 2 experiments

Mark Nelson [a,b,c,*], Kathelin Gray [a,b,c], John P. Allen [a,b,c]

[a] Institute of Ecotechnics, London, UK
[b] Institute of Ecotechnics, Santa Fe, NM, United States
[c] Biospheric Design Division, Global Ecotechnics Corporation, Santa Fe, NM, United States

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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

* Corresponding author at: Institute of Ecotechnics, Santa Fe, NM, United States.
E-mail address: nelson@biospheres.com (M. Nelson).

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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

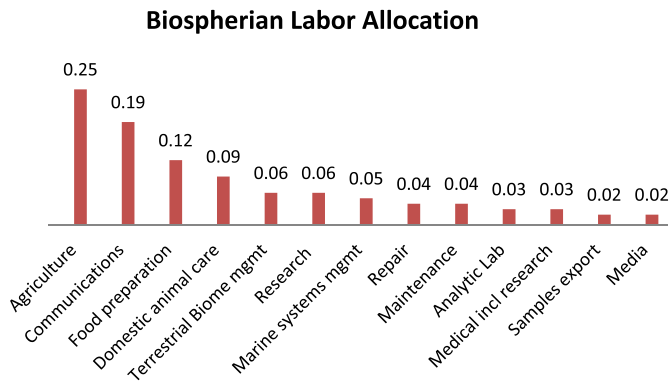

Fig. 3. Allocation of crew time during first Biosphere 2 closure experiment (Allen and Nelson, 1999).

Mission Control didn't understand what it was like carrying out the objectives inside. "We're inside the dome, and they aren't and they haven't a clue what we're going through" (Nelson, unpublished). "Some crew members thought communication with "mission control" was difficult (despite video conferencing, e-mail, phone, etc.), a feeling exacerbated by frustration over a perceived insufficient level of support from the outside" (MacCallum et al., 2004). In studies of NASA astronauts, it was found that if the crew thinks there is lack of compassion, displaces anger and frustration on Mission Control (ground support), does not have a full understanding of management decisions, and desires more autonomy, morale can be affected (Kanas and Manzey, 2003).

5. **Power struggles, inside and out**. During the two year closure, it became apparent that there was a power struggle between owners of the project over its management and direction. These external events exacerbated polarization and conflict within the inside crew. Some inside wanted to continue with the original purpose and management of the facility and others sided with a small faction of the project's Scientific Advisory Committee which inserted itself into the power struggle and who wanted to change the management structure. They advocated less emphasis on operating as a closed system, including importing food to lessen workloads to increase time for more conventional research (Poynter, 2006; Reider, 2009). The project management and the rest of the crew wanted to continue learning to operate Biosphere 2 as a closed system as a priority on this first "shakedown mission," collecting extensive data for later analysis and accomplishing as much research as possible. This tension between time for operational duties like farming and more purely research activities echoed conflicts between "sailors and scientists" experienced in Antarctica and on expeditions (Finney, 1991) although Biosphere 2 crew did both. It is impossible to calculate how much external events may have intensified divisions and stress within the crew, but it certainly increased tension and raised the stakes.

6. **Media attention**. In response to public demand, the project management allowed extensive press interviews and coverage of the experiment. Press coverage fluctuated between praise and dismissal. Media attention and the responsibility for interviews took much emotional energy.

7. **Criticism from some academics and scientists**. As H.T. Odum (the inventor of ecological engineering and co-inventor of systems ecology) noted: "The self-organizational process of Biosphere 2 was a beautiful living model with which to study aspects of the larger earth by comparison, but when journalists asked establishment scientists, most of whom were small-scale (chemists, biologists, population ecologists), they got back the small-scale dogma that system-scale experiments are not science" (Odum, 1996).

8. **Privacy**. The project's goal to share the excitement of "real-time science" with the public succeeded; there were half a million visitors to the site during the 2-year initial closure. The crew had to get used to being watched as they worked in places visible through the glass. Efforts to ensure privacy when needed included private crew bedrooms (which other crew needed permission to enter). The entire habitat area occupied the second floor out of view of visitors, private phone lines, computers for sending/receiving email. Interior space and dense growth in biomes also provided privacy in secluded locations.

9. **Social valency, personality conflicts and cabin fever**. Scientists have observed that larger crew sizes enhance social diversity but increase the danger of schisms and subgroup factions (ISU, 2009). The Biosphere 2 crew worked together extensively during training and came in as friends, in some cases long-term friends, but tensions inside split the group. Nevertheless, they had to work together on many tasks, share some 2200 meals together, and interact daily with the same group of seven others. The two groups which cohered better socially took opposite sides of the management conflict. Cabin fever refers to annoyances that can build up when there is no escape. Admiral Byrd noted: "I knew of one who could not eat unless he could find a place in the mess hall out of view of a [person] who solemnly chewed twenty-eight times before swallowing. In a polar camp, little things like *that* have the power to drive even disciplined men to the brink of insanity" (Byrd, 1938).

10. **Oxygen decline, elevated carbon dioxide**. Amongst the most unexpected and interesting occurrences of the first two years was a gradual decline in oxygen, falling from 20.9% to around 14% over the first sixteen months (Severinghaus et al., 1994; Nelson and Dempster, 1996). Probably because atmospheric pressure did not change, there could not be the same adaptation as in mountain-climbers. Several crew developed sleep apnea (though supplemented by oxygen lines run to their bedrooms at night from the analytic laboratory) and, coupled with the caloric restricted diet, this diminished energy and possibly cognitive abilities (Walford and Spindler, 1997; Walford et al., 1996) until oxygen was replenished 16 months into the closure. Carbon dioxide levels were much higher than ambient, reaching highs of over 4000 ppm during winter months (Nelson and Dempster, 1996). These levels are comparable to Space Shuttle at 5000–10,000 ppm and International Space Station levels at under 2000 to 9000 ppm (James et al., 2011).

11. **Sex/gender**. There were four women and four men in the crew. There were two couples who bonded before entry (and remain together twenty years after the closure experiment). Two individuals were in no sexual relationship, and two left partners outside. The tensions underlying actual and fantasized sexual liaisons or attractions – jealousy, intrigue – always powerful in human groupings, perhaps grow more so in isolated, confined groups. Psychological studies on male Antarctic and submarine crews were one of the vectors that led to a decision for an equal gender mix in Biosphere 2. Including women has been found to relieve pressure and help normalize the culture of isolated groups. Women perform as well or better than men in these circumstances (Connors et al., 1985).

5. Alleviating factors

1. **Perceived historic importance of undertaking**. Studies of submarine crew demonstrate that people selected for challenging environments are highly motivated to perform in very difficult circumstances (Helmreich, 1974). The biospherians had volunteered and competed with a larger group of candidates for the privilege of carrying out the unprecedented closure experiments. They had extensive training and were key participants in the construction, botanical/animal collections and preparations for the experiment. As has been noted of astronauts and other expeditionary crew, belief that what one is doing is of historic importance of-

Fig. 4. Biospherian handshake: Mark Nelson with John Allen (left), inventor and Executive Chairman of the Biosphere 2 project and Academician Oleg Gazenko, Director, Institute of Biomedical Problems, Moscow (photo by Abigail Alling, Biosphere 2, 1991–1993).

Fig. 5. Biosphere 2 crew at first Interbiospheric Arts Festival in exchange with outside artists and performers (photo by Abigail Alling, Biosphere 2, 1991–1993).

ten influences the willingness to deal with hardship and stress (Suedfeld, 1991). The "heroic mode" can also lead to people pushing themselves past their maximum (Allen, 2002).

2. **Diversity of shared and private spaces within Biosphere 2**. For a confined environment, the facility offered relatively spacious and attractive locations for both shared and private functions (these are detailed in Alling et al., 2002). Bechtel et al. (1997) identified some 50 behavior settings and found that each biospherian had 3.5 behavior settings, more than three times that available to the population of a small town. Each had a personal apartment with upstairs sleeping loft and downstairs living room.

3. **Communications with the outside**. The closure experiments (1991–1994) coincided with early years of the Internet, and email and video linkups with Mission Control and consulting scientists and engineers were available. Telephones were installed at a place where crew could speak with friends/family. Evolution of communications change the nature of isolation and confinement. So while only eight people lived inside Biosphere 2, biospherians maintained a complex social life through meetings at the glass (Fig. 4) and digital communications.

4. **Creative expressions through the arts**. The biospherians painted, wrote poetry, performed music and pursued photography/video. One crew member did an electronic link with a performance artist traveling around the world during the two year closure. There were occasions when the biospherians held "interbiospheric arts festivals" presenting their work and listening, seeing the work of outside artists (Fig. 5). Many kept journals, wrote scientific and popular papers and books including a cook book of the best recipes (Silverstone, 1993).

5. **Public and school support**. Biospherians got morale boosts interacting with enthusiastic and supportive visitors. They did linkups with school groups – from K-12 to university groups – either with those directly outside the facility (linked by 2-way radios) or via phone.

6. **Nature and beauty**. Biosphere 2 was designed to be beautiful and awe-inspiring. Minimizing or eliminating off-gassing of materials was a design priority. The interiors utilized natural fibers and wood wherever possible, and the healing effect of being surrounded by luxuriant vegetation helped mitigate the feeling that the crew was deprived and isolated. A growing body of evidence supports the health and psychological benefits of an environment with green plants (Clay, 2001). The environment was pollution-free compared to urban settings. There was more natural diversity encountered inside Biosphere 2 than is available to most people (Fig. 6).

7. **Feeling yourself a vital part of a larger whole**. As space crews also reported, the biospherians felt like they could respond to whatever their world needed – changing irrigation times, maintaining and repairing equipment, preventing invasive species from over-running areas of the biomes, working to maximize use of "sunfall" with additional plantings to counteract CO_2 rise and increase food supply. Connectedness of all vectors was an important factor in why Biosphere 2 could operate – and the feeling of being able to respond empowers. Each biospherian reported a deep sense of being part of a living system. The crew were caretakers, keeping machinery going to ensure water availability, temperature control, etc. They also realized that without their ecosystem, they would not survive. Understanding that Biosphere 2 was the crew's "life boat" (life support system) may have helped the success of the mission. The crew understood that "the health of the biosphere is synonymous with our health" (Alling and Nelson, 1993).

6. Crew selection and training

The Biosphere 2 crew, for the first closure experiment, ranged in age from 29 to 67, from different socio-economic backgrounds, from technically skilled high school graduates to graduate level professionals and medical doctor. Five were from the US, two from the UK and one from Belgium.

All candidates received extensive and intensive training prior to the closure. They had all worked in small group settings at various

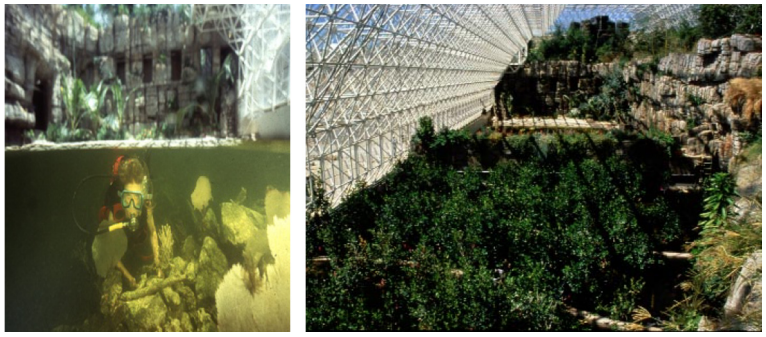

Fig. 6. Abigail Alling taking care of corals in the Biosphere 2 ocean (left), and view of the mangrove ecosystem with rainforest at the top and savannah cliff to the right (photo left by Peter Menzell, right by Gill C. Kenny).

remote settings such as Institute of Ecotechnics-consulted projects in West Australia and aboard an ocean-going ship learning maritime skills, and creating and performing theatrical pieces. They had also worked at the Biosphere 2 facility during construction, operating the onsite prototype farm and other systems developed for the facility. They started with others in a larger group of biospherian candidates, and finally trained as a team preparing for the closure experiment.

7. Group dynamics theory – the Bion approach

An important tool for dealing with group dynamics in Biosphere 2 was familiarity with the work of W.R. Bion who studied small group behavior (Allen, 2002). Working at the Tavistock Clinic in the UK in the 1940s, he worked with "shell-shocked" (the then current term for post traumatic stress disorder) pilots relieved of duty during World War 2. The objective was to see if they could return to health and rejoin their combat unit.

Bion demonstrated that a small group operates under specific patterns of behavior differing from individuals or large groups. This unconsciously generated behavior, unless brought to light, defeat a task group's commitment to achieve their purpose. Specifically he discovered three sets of unconscious behavior in small groups (Bion, 1961). These operate during "group animal" mode, as opposed to the "task group" mode, which carries out their accepted task, and can be short-lived or can operate for extended periods of time when the group has lapsed off-task. All three of these behavior patterns sabotage the task. One dysfunctional characteristic is an unrealistic treatment of resources and the time needed for completion of tasks.

(1) Fight/Flight, in which the group alternates between fighting, and fleeing from the task. This manifests in a myriad of ways such as not showing up at meetings or constant arguing about strategy and purpose.

(2) Pairing, in which the group abdicates leadership and thinking to a twosome, then passively waits for that pair to decide what the group should do.

(3) Kill the Leader/Dependency. In the former, the group attacks whoever leads in setting an agenda or procedure. In the latter, the group becomes incapable of independent action, and mimics childlike dependency.

Bion found that this "group animal" arises not only in combat conditions but in industrial, political, educational, social and family situations.

8. Bion group dynamics during the Biosphere 2 closure, 1991–1993

These phenomena manifested in Biosphere 2 during Mission One (1991–1993). During the training of the crew, off-site and onsite, they had worked with Bion's discoveries of group dynamics. This included years of training and working at the Biosphere 2 facility location, including seven week-long simulations of closure before the start of the experiment. Education in recognizing usually unconscious group behaviors undoubtedly assisted the first closure to succeed, remain and work together for two years despite expected and unexpected difficulties.

In addition to training in observations and techniques prior to closure, the biospherians re-read Bion during the two year closure. "At crucial moments…meetings were called by the biospherians to review their group dynamic training and the current situation" (Allen, 2002).

The "group animal" manifested through occasions of contempt and disdain for top management inside and outside the facility, and the feeling amongst some of the crew that Mission Control was over-specifying and controlling the work schedules

Fig. 7. View of the Biosphere 2 farm from the balcony of the habitat (photo by Abigail Alling, Biosphere 2, 1991–1993).

(Nelson, unpublished; Poynter, 2006). Walford saw "intense factionalism (a split between those who strongly supported and those who strongly resented interference from Mission Control)" (Walford, 2002). Perhaps the length of the mission increases the desire for more autonomy, as has been speculated will be true for Mars expeditions and long-term space habitation (ISU, 2009). In Biosphere 2, considerable latitude was given for the crew to organize its work schedule as it saw fit, and every member of the crew could allocate time for research projects of particular interest, unlike space crews who are rigorously scheduled.

There were also instances of the "Fight/Flight" basic assumption group during the two years. Though only one thrown teacup was a manifestation of explicit anger, there were numerous episodes of argument and bickering. Flight mostly manifested in some occasionally refusing to eat with the others, and absences from planned social events.

Despite ups and downs in group morale and times of interpersonal friction, the group of eight remained unified in accomplishing their tasks and cooperated to achieve operational and research objectives. Intense factionalism has been often seen in remote exploration as well as in space crews. "Your difficulties in Biosphere 2 were nothing compared to our cosmonauts" (Academician Oleg Gazenko, long-time Director of the Institute of Biomedical Problems, Moscow; Gazenko, 1993).

9. Food concerns – a similarity with early Antarctic and other expeditions

Like earlier remote expeditions and Antarctic exploration, food was a prime concern inside Biosphere 2. Antarctic researchers note that this is not of much concern currently, given the ease of robust initial supply. Studies report concerns that are more about family and love relationships enduring separation and fears of abandonment and rejection (Suedfeld, 1991). But the agricultural system – crop rotations, concern about pests and low-light seasons diminishing harvests – were all of prime concern to the biospherians (Fig. 7), who understood "if we want to eat it, we have to grow it." Similarly, there was a huge interest in meals – first, to alleviate hunger – but secondly, there was a keen appreciation for well-presented and new ways of working with staple foods.

It is striking that cosmonauts on Mir space station, even those without much interest in gardening on Earth, felt buoyed by the presence of small green plants and tended them with great care and fondness. During the two year closure, in January 1993, the Biosphere 2 crew linked via ham radio to the US South Pole base over-wintering crew, and heard their excitement at the prospect of a greenhouse being installed so they could have fresh lettuce and green plants, in the midst of their icy white world (Nelson, unpublished).

Fig. 8. Biospherian crew gathered for a feast (photo by Roy Walford).

10. Evolution of the Biosphere 2 life style

Small, isolated over-winter crews in Antarctica develop distinctive subcultures, with each station differing from others (Palinkas, 2002), reflecting the human need to create a cultural order to lend meaning especially in new and unfamiliar environments (Hallowell, 1955).

A weekly event format that had been evolved and practiced continuously over decades at Institute of Ecotechnics' field projects, was followed initially by the biospherians. This included a short morning meeting at breakfast to discuss the day's work, Tuesday cultural dinners on themes of different types, Thursday night readings and discussions of topics of personal development and the history of philosophy, Saturday morning movement/acting workshops and Sunday night celebratory dinners with toasts and individual speeches (Alling et al., 2002). Improvisational theater and movement sessions have been found to catalyze emotional mechanisms and improve morale in long-term group projects, enabling role exploration and team-building (Allen, 2002).

During the two years, new elements of the biospherian life style emerged. One development was that every public and traditional holiday was taken as well by the crew. This happened quickly and provided a cultural link and cultural cohesion with the 'outside' world. During the first three months when the daily caloric intake reached its lowest, it was quickly decided that it wasn't a proper holiday without a feast. So food was put aside in a systematic way, reducing normal provisions, so that there'd be extra for the feast day. Meat from pigs, chickens and goats, goat milk and chicken eggs from domestic animals raised in Biosphere 2, though a small part of overall nutrition, added variety to the diet. People voluntarily prepared special food for feasts, home-brew fruit wine, sausages, cheeses, decorative cakes and pies, etc. Every birthday also became a feast day, and to improve months without a holiday, the crew invented special feasts – a peanut or sweet potato harvest celebration, so no month passed without a feast (Fig. 8). Meat was reserved for Sunday night dinners or for celebrations. Since there were only young, small coffee trees in the rainforest, coffee beans were few but treasured. There was one Sunday morning cup of coffee per person, every few weeks (Silverstone, 1993; Alling and Nelson, 1993).

For variety, the crew sometimes dined in special places. Two favorites were on the sandy beach on a beach blanket or on the terrace of the habitat overlooking the farm. Both psychically felt like eating "outside" and enjoying the night sounds of the facility – a mix of natural sounds like crickets and frogs and mechanical ones like the roar of the vacuum pump which produced the gentle waves in the ocean.

The impact of a feast or special food was great. No matter what the prevailing group mood, all conflict was put aside as the biospherians feasted and partied together. It is striking re-reading a daily journal (Nelson, unpublished) to see how much group morale and cohesion fluctuated – all the way to the end of the two year closure.

11. Group cohesion – caring for the life boat overrides other agendas

Considering all the mission elements including diet, work load and material seal, there is no question that group dynamics' impact on interpersonal relations was the most difficult challenge of the two year experiment (Alling et al., 2002; MacCallum and Poynter, 1995). The social dynamics of crews in isolated, confined, extreme environments where division into cliques is a dominant vector has been shown in Antarctica to have psychological and health impacts. Those crew experience more tension/anxiety, depression and anger (Palinkas, 2002). Furthermore, crew who feel powerless have more difficulty in adjusting to the demands of their environment (Palinkas, 2002). So it may not be coincidental that those who experienced greater difficulty from reduced oxygen, and who sought personal counseling via phone were members of the faction wanting mission change (Walford et al., 1996; Nelson, unpublished). Despite the feelings of some of the biospherians that the stress from the internal discord made them depressed (Poynter, 2006), objectively this was not the case. Strikingly, the MMPI psychological test administered to both the first and second closure crews showed low scores for depression. The women and men tested very similarly, and there was a high correlation between the test results of the entire crew and a group of astronaut candidates. Overall, test results indicated an "adventurer" profile, a personality well-suited to challenge and stress (Bechtel et al., 1997).

Suedfeld (1991) points out that the crucial determinant of individual and group dynamics is not only objective environmental characteristics, but the experienced environment. From that perspective, Biosphere 2 was experienced in a very particular way by its first group of inhabitant explorers. The initial closure crew had helped design and build Biosphere 2, spending several years before closure doing species collections, working on-site, training in on-site greenhouses and in the final year inside Biosphere 2, planting in all the biomes and agricultural area. As Walford put it, "[the crew] poured the cement, did the electrical wiring, designed and installed the computer systems, and participated in expeditions to sea, desert, savanna, and jungle to collect the 3800 species that made up the flora and fauna of Biosphere 2. Biosphere 2 therefore became "our baby" (Walford, 2002). Alling et al. (2002) underline the importance for long-duration space crews to participate in the design/installation of their life support systems.

Despite challenges to the project's direction and the at-times bitter factionalism which developed inside, it did not affect either the operation of the Biosphere 2 facility and life systems, nor of anyone's area of responsibility or research work (Fig. 9). Crew workloads reflected the principles of "work democracy" where each person has unique areas of responsibility as well as working in teams (Allen, 2012; Alling et al., 2002). The success of the Biosphere 2 closure experiment reflected passion for the goals of the endeavor, the role the biospherians themselves had taken in making the facility and the commitment made by each of the crew to complete the two year mission (Alling et al., 2002). Undoubtedly, a help was having studied the history of scientific expeditions gone awry, using Bion's analysis periodically to discuss what was happening so that everyone was reminded of the vicissitudes of group dynamics.

The crew knew that anything which hurt living or technical systems might quickly and directly imperil their own health. They kept overall Biosphere 2 air and water quality, carbon dioxide and oxygen levels in constant attention, in a very visceral and profound way, not just as a mental abstraction. This intimate "metabolic connection" enabled the crew to discern and respond to even subtle changes in the living systems (Alling et al., 2002; Alling and Nelson, 1993). Appreciation of the value of biosphere interconnectedness and interdependency was appreciated as both

Fig. 9. (Left) Crew celebrates after cutting of the savannah grasses to sequester carbon in the seasonally active biome before the first rains started growth (photo by Linda Leigh). (Right) Party in the Command Room of Biosphere 2 (photo by Roy Walford).

an everyday beauty and a challenging reality. That deep sense of connection of all life forms may well be even more the case for permanent habitation in space with bioregenerative life support systems.

12. Conclusions

The overall task must be well understood and agreed to, especially if the mission itself is complex and multi-faceted. Allen has noted the importance of distinguishing the overall "expedition" from the numerous experiments and research programs (Allen, 2002).

Food production is an issue which has not been relevant in past short term space missions, but will be of crucial importance as missions become longer and life in space must become self-sustaining. Green plants provide some of the intangible emotional sustenance that people derive from contact with other living organisms.

The impact of special feast days and special "euphorics" – wine, coffee, etc. – are invaluable as morale-boosters for long-duration missions. Adequate time for recreation and creative outlets such as personal art and expression projects can be important aides for emotional well-being. With all its challenges, life in space needs to be rich in ways desired by the participants. Long-term missions and permanent habitation require a way of life to be created, one with opportunities for relaxation, personal expression and social interaction other than those that are task-oriented (Alling et al., 2002).

Group dynamics needs to be studied during training, and explicitly discussed during the mission. Using the Bion group dynamics methodologies may be advantageous both in training and in periodic evaluations during the missions. Individual private counseling should be made available for those who desire it. Psychological testing before, during and after the mission is important.

Positive feedback on accomplishments are quite important for an isolated crew. In Biosphere 2, this included visitors, on- and off-site school groups, and linkups to scientific conferences and workshops.

Individuals need to be pre-vetted for emotional well-being and tolerance for heterogeneity of culture/gender/background. Pre-mission intensive group tasks that build team understanding and coherence is invaluable. Their ability to tolerate ambiguity and handle the unexpected can be evaluated during training settings. However, even when participants are well-tested and consider themselves friends, the stress of challenging tasks, personal and work dynamics, and environments can fray even deep bonds.

It is important not to over-rate group dynamic difficulties and emotional fluctuations. Isolated groups tend to attach greater significance to what is after all, very common in all human groups. Some earlier anecdotal reports from polar station crews seem to have exaggerated psychological problems (Oliver, 1991). Similarly, doubtless there was unconscious exaggeration of the feelings of the crew inside Biosphere 2 regarding personal psychological issues. And just as astronauts are eager for more space flights despite lack of privacy and intra-crew difficulties, completing a mission that involves being part of a confined, isolated small group may also be a character builder. Long-term studies of Antarctic personnel indicates that despite the stress of their time there, there are long-term benefits from succeeding (Palinkas, 2002). The eight biospherians from the first Biosphere 2 closure of 1991–1993 have continued their lives with distinction. This accords with studies done of astronauts who report a sense of adventure and achievement after their mission, suffer no short-term nor long-term psychological effects and become mentally stronger as a result of the experience (Suedfeld and Steel, 2000).

The crew should be given as much autonomy as is consistent with overall project/mission objectives. This should be explicit from the outset. Let them organize their work crews, decide on holidays, feasts and special events. Since they have been selected because of their high motivation and commitment to overall objectives, they will focus on their accomplishment and do whatever it takes within their power to overcome obstacles that arise.

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