Chapter 7: A HYPERCYCLE MODEL OF COMMUNITY-SCALE SUSTAINABLE DEVELOPMENT

All of the individual case studies described in the previous section deal with focused efforts to achieve sustainable development in a particular way. Each case study can be conceived as being independent from the others but, in fact, they are related, at least by the people who have been involved. Either directly or indirectly the co-authors of this book have been in all of the case studies, along with other efforts that had less involvement from University of Maryland students in travel-study classes. Also, the Belizean staff at the Possum Point Biological Station has directly participated in or facilitated all of these activities. Finally, various people in Sittee River have been touched in one way or another by the case studies, which extend the involvement even further. To account for the interactions between the case studies, we offer a broader model of local, community-scale sustainable development in this section. Specifically, the model is a theoretical way of conceptualizing what we think may be happening in Sittee River because of the presence of the biological station. However, it is also a general model that might be applied to other situations where multiple projects in sustainable development are undertaken in an isolated village setting.

The model for sustainable development is based on an analogy with the origin of life. Sustainable development and life are suggested to be similar kinds of general systems phenomena that can arise through emergence. Eigen's hypercycle model of coupled sets of autocatalytic chemical reactions is used as a basis of the analogy. In this conception people of a community are analogous to chemical molecules and their activities are analogous to chemical reactions. Presence of social catalysts, a critical mass of participants and a balance between income generation and conservation activities are suggested to be necessary for sustainable development to emerge. The model is used to describe how sustainability might be achieved and maintained within a small, rural community such as Sittee River.

The Hypercycle Concept

Manfred Eigen, a German biochemist, first introduced the concept of the hypercycle in the early 1970s and later elaborated the concept with colleagues, especially Peter Schuster (Eigen 1971, 1992, Eigen and Schuster 1979). A hypercycle is conceived as a system of autocatalyzed chemical reactions that can outcompete alternative chemical reaction systems for substrates and that can evolve through natural selection. It is suggested to be the highest level of biochemical organization. The reaction system of a hypercycle consists of a closed circuit of autocatalytic units in which each unit both instructs its own reproduction and provides catalytic support for the reproduction of the next unit in the circuit (Figure 7-1). It is then a cyclic arrangement of catalysts which themselves are cycles of self-replicative reactions. Hypercycles are thought to emerge when the positive feedback of a self-reproducing chemical network creates hyperbolic increases in reactant concentrations.

Eigen and his colleagues have developed the hypercycle concept through the construction of theoretical models and through experimentation with viral systems. The

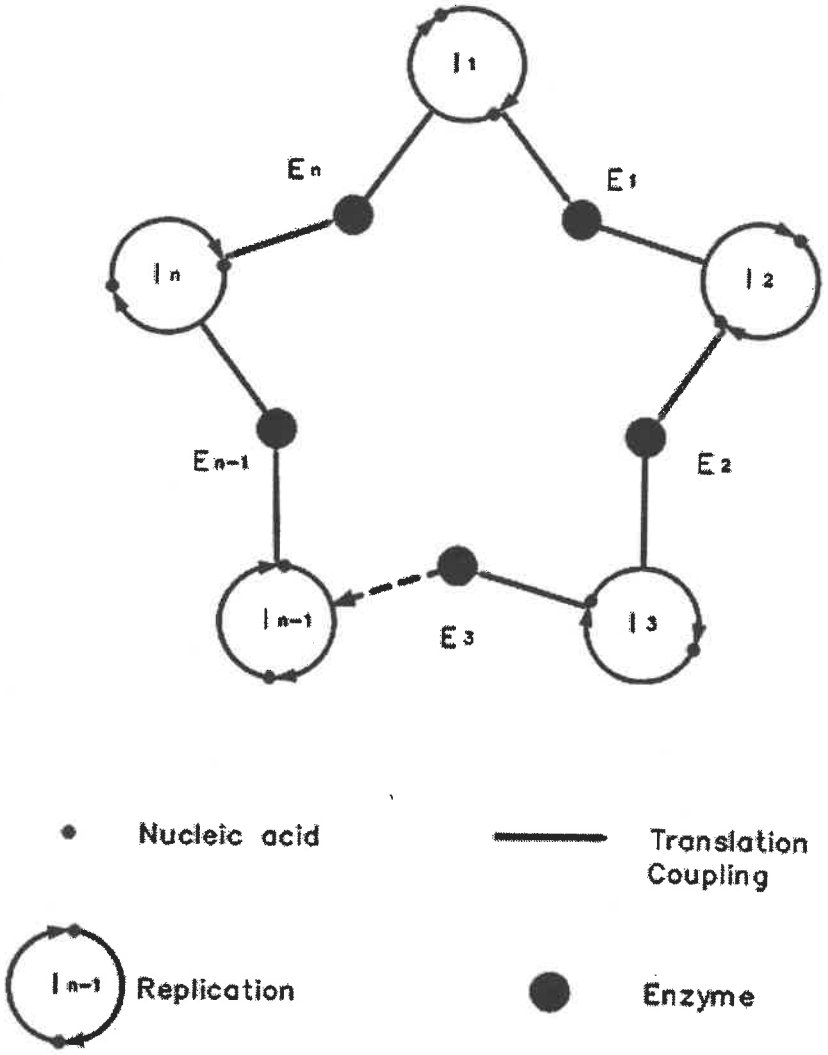

Figure 7-1. A model of coupled self-replicating chemical reactions of a hypercycle (redrawn from Eigen 1971, 1992).

most important contribution of the concept has been to provide a hypothetical explanation for the origin of life, from prebiotic chemical reactions to primitive replicators to the origin of RNA and DNA molecules as information carriers. Although the concept has been criticized (King 1981, Yockey 1992), it remains an important starting point for understanding the origin of life and for self organization in general (Jantsch 1980, Kauffman 1993).

An Application to Sustainable Development

The hypercycle concept can be applied to sustainable development through an analogy with the origin of life. Both sustainable development and life are self maintaining processes that generate metabolism (material transformation and turnover) and increased organization. According to most accepted theories, life arose from non-living components and it has continued to evolve into many forms representing the Earth's biodiversity. Analogously, it is hoped that sustainable development will arise from the apparently non-sustainable component systems of today's society and it will evolve into a variety of human cultural systems of ecologic-economic linkages. The origin of life and the origin of sustainable development can be thought of as emergence processes (Morowitz 2002, Holland 1998, Johnson 2001). In these kinds of processes the higher level phenomena are said to emerge from the interaction of the lower level phenomena through self organization. Thus, at some point in time after the formation of the planet Earth, about 3.5 billion years ago, living organisms arose from non-living chemical compounds in some kind of primordial soup. This occurred by the self-assembly of small organic molecules into larger, more complex molecules which then were able to maintain and replicate themselves in an organized way. The hypercycle concept is one model that explains the emergence of life through enhanced autocatalysis.

Instead of coupled chemical reactions, sustainable development in a social system can be conceptualized as coupled activities conducted by humans. Just as chemical reactions occur when reactants interact to form products, people and resources interact through various forms of social activities to produce finished products and to spread ideas. Also, just as chemical reactions can be catalyzed by enzymes or other factors, social interactions can be catalyzed by people with knowledge or passion or by other kinds of incentives. Figure 7-2 shows the basic structure of the social reaction model in the energy circuit language. Reactants of people and information combine in social activities producing people with new ideas and new information. This basic model is extended in Figure 7-3 to represent a hypercycle of interacting social activities. Here three of the basic social reactions are connected so that the products of one activity become the reactants of the next activity and so on. Potentially, this whole network becomes autocatalytic. The network will continually regenerate itself and can be stimulated by adding people or information into the system.

Set theory is used in Figure 7-4 to begin to relate the hypercycle model to sustainable development. Two overlapping subsets of people are shown within the larger set of the total population of a human community. The main set is the total population in a community. Each subset within the total set represents the group of people who are involved in particular kinds of activities. The set on the left hand side of the figure includes all people who are involved with conservation activities while the set on the

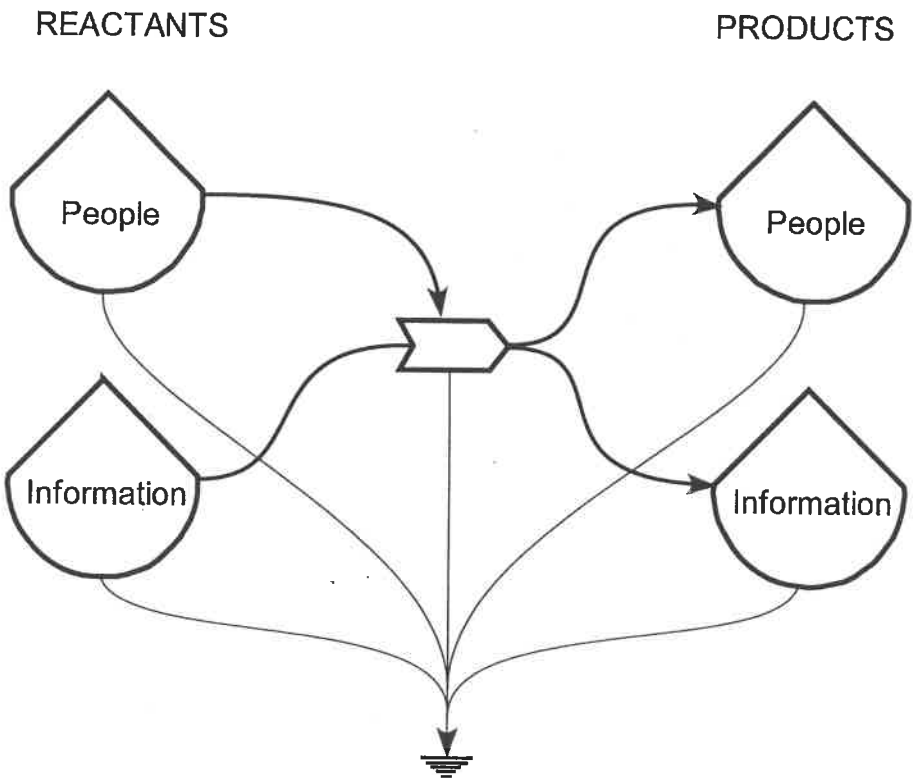

Figure 7-2. Energy circuit diagram showing the analogy of the social interaction of people as a chemical reaction with reactants coming together to generate products.

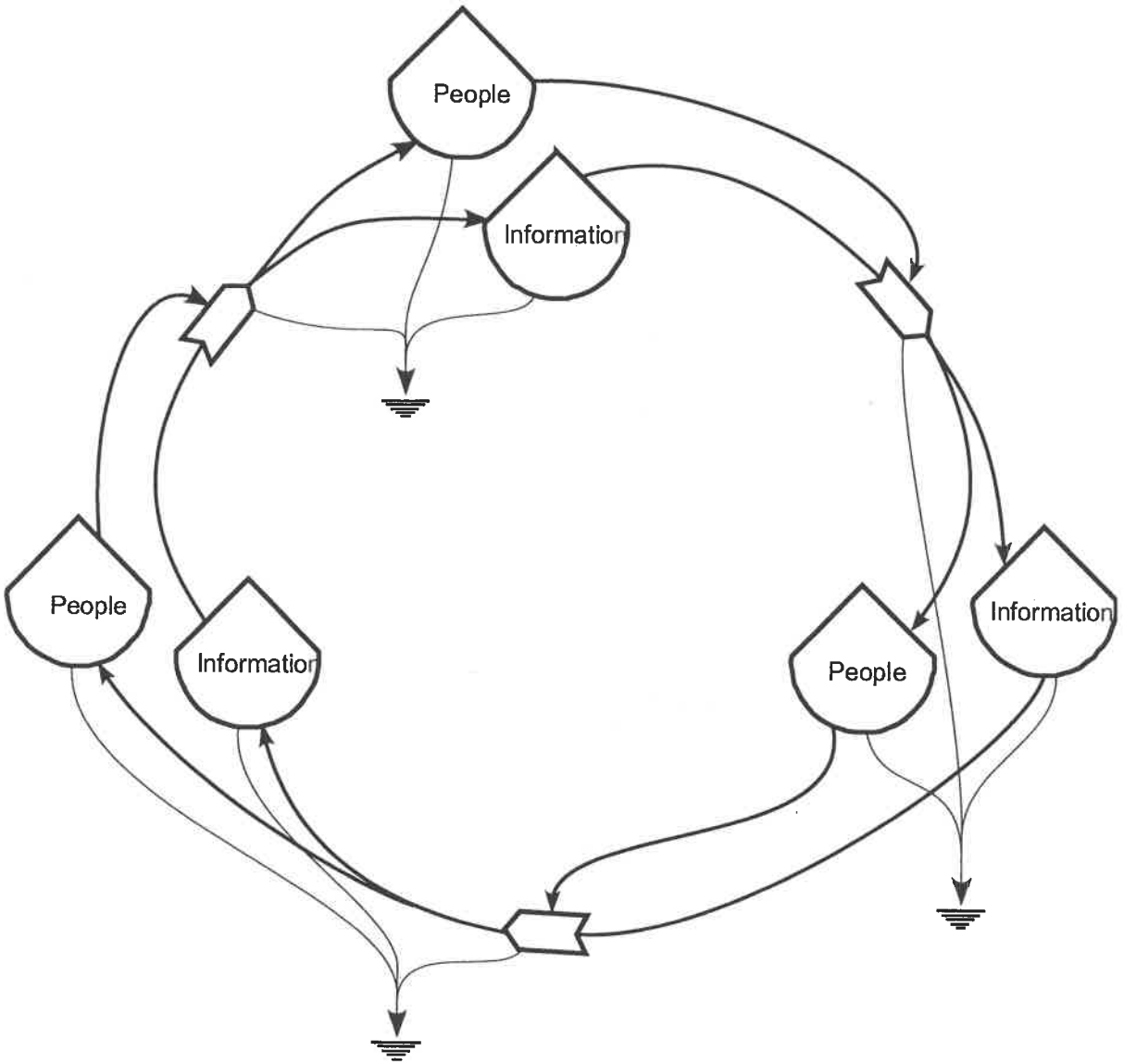

Figure 7-3. Energy circuit diagram of coupled social interactions (see Figure 7-2) forming a hypercycle in which one interaction catalyzes the next.

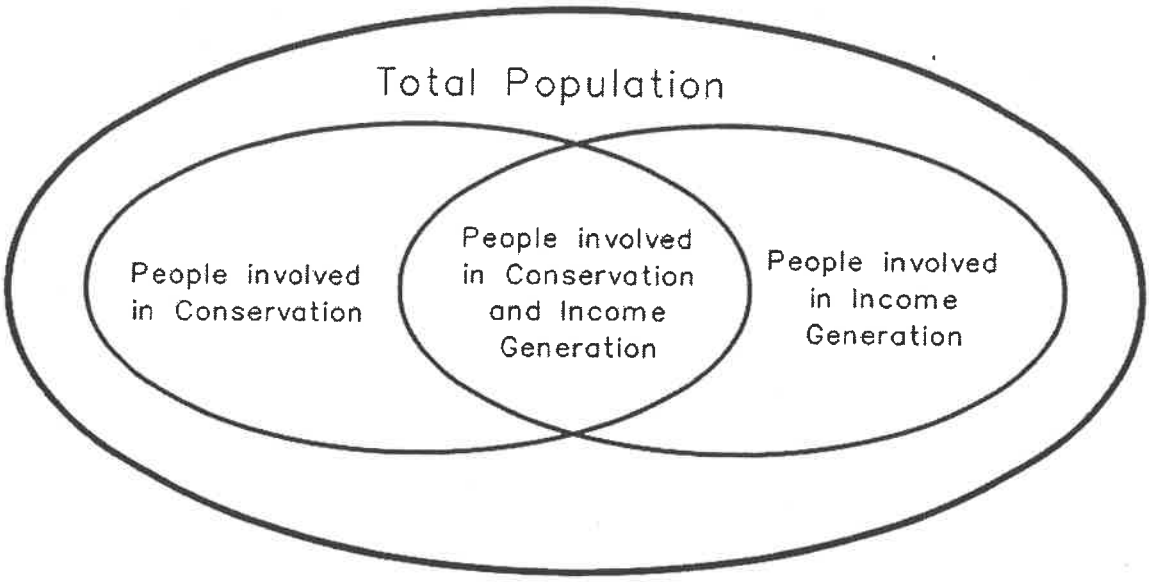

Figure 7-4. Set theory representation of groups of people in a community who participate in different types of activities.

right includes all people who are involved with activities that generate income. The overlap between the two sets represents people who participate in both conservation and income generating activities. It is hypothesized that for sustainability to be achieved, a balance must be reached between the activities that relate to conservation and ecological value on one hand and the activities that relate to generating income and economic value on the other hand. This view is analogous to the chemical reactions from the original hypercycle concept, where people in the zone of overlap are social catalysts who have interest in maintaining both the conservation and income generation activities and who serve to bring more people from the community into the activities. Key unknowns in the model, at present, are how many people are required to participate in the combined activity sets and how much overlap in the sets is required for a hypercycle of sustainability to be initiated and maintained.

Many kinds of cultural activity subsets take place simultaneously in actual communities and there may be certain special combinations of overlaps that facilitate community development and lead to sustainability. Figure 7-5 shows the hypercycle model from Figure 7-1 in set theory. Subsets represent individual self-replicating reaction systems that correspond to activities conducted by people within the community. Enzymes are shown in the zones of overlap between subsets that correspond to individuals who participate in both subsets of activities. A hypercycle can emerge from the linkages of the subsets into greater cyclic patterns that draw more and more people in the coupled activities. It is suggested here that at the most basic level, the rate (or speed) of social interaction within the sets of social activities follows the Mass Action Principle from General Systems Theory (Lotka 1956, von Bertalanffy 1968). This principle is best described by chemical reactions and it holds that, all other factors being equal, the rate of a reaction is directly proportional to the concentration of the reactants. By analogy then, the rate of a social interaction would be directly proportional to the number of people involved. It is therefore assumed that a large proportion of the total population must be involved in the sets of activities and interactions for a social hypercycle to emerge within a community. The Mass Action Principle has been widely used in epidemiology to describe the transmission of disease according to physical interactions of people (Heesterbeek ____) and it seems to offer a reasonable basis for the model of social interactions in the sustainability hypercycle. Furthermore, the analogy between chemical systems and social systems is similar to the popular analogy between economic and social capital (Lin 2001). The later analogy is being used to understand how actions take place in relation to connectedness and participation of people in social systems and it may provide an alternative but related foundation for building a model of community-level sustainability.

An Ongoing Application

The case studies of activities being undertaken by the authors and associates in Sittee River can serve to illustrate the hypercycle model of community-scale sustainable development. The model of some of the relevant activity sets that are on-going in Sittee River is shown is Figure 7-6. Descriptions of the activities in the figure were given in previous sections. The activities are on-going and some have been more successful than others. Taken together they form an application of the hypercycle model for sustainable

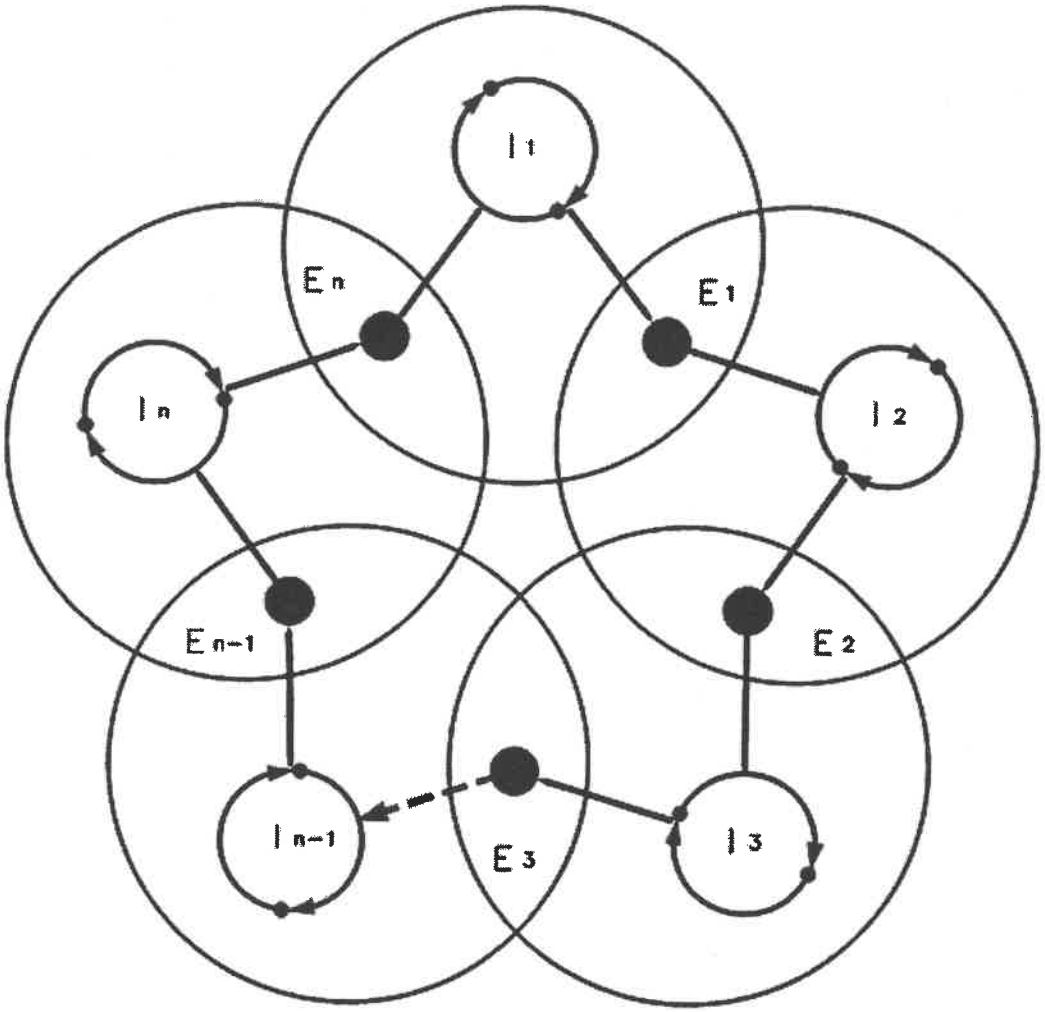

Figure 7-5. A set theory translation of Eigen's hypercycle model. Subsets are drawn around individual self-replicating reactions from Figure 7-1.

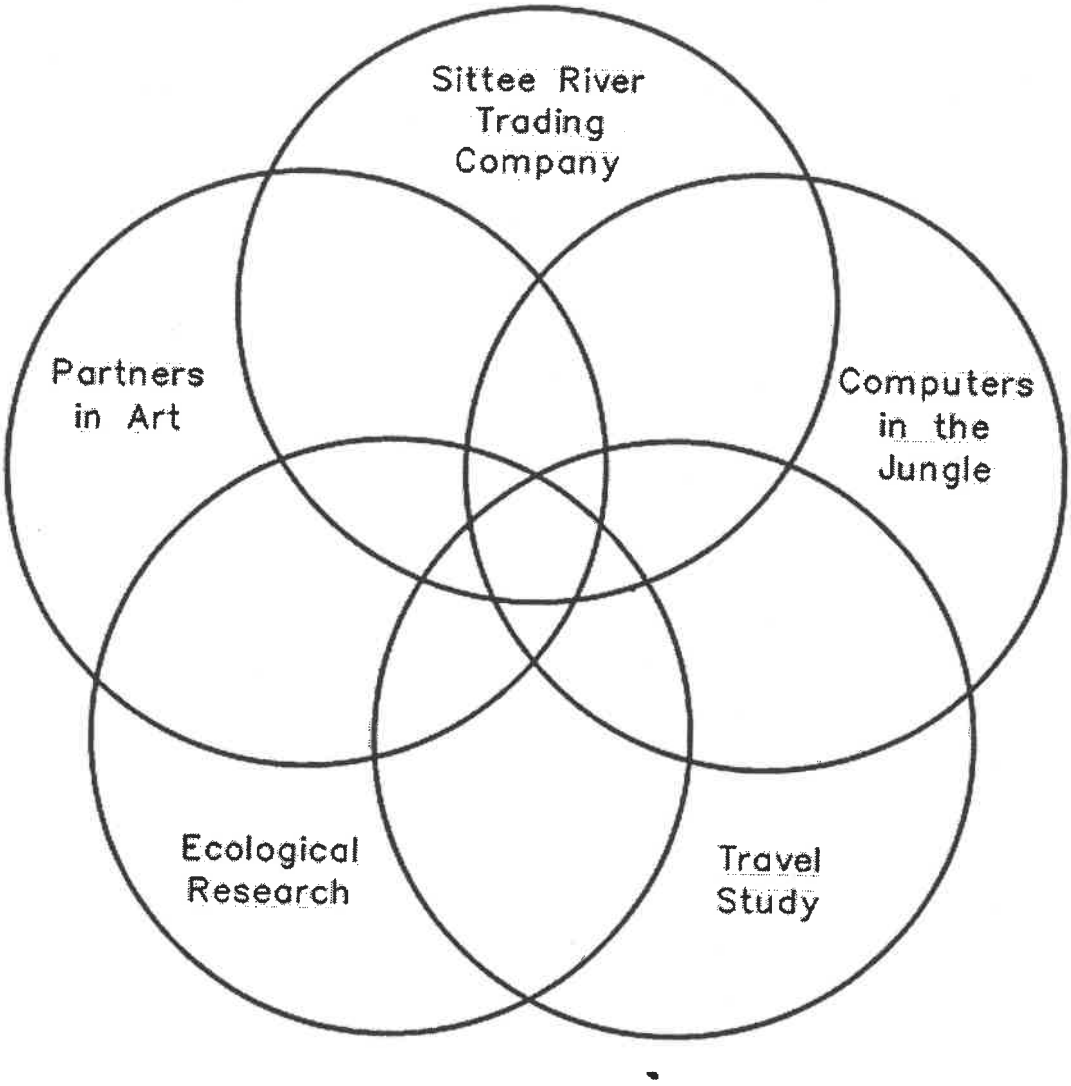

Figure 7-6. A hypercycle model for activity sets from Sittee River village that may lead to the social emergence of sustainability at the community-scale.

development in Sittee River village. One key is the overlap between activity sets. As shown in Figure 7-6, there is a small zone of complete overlap in the middle of the diagram, meaning that there are at least a few people who participate in all of the activities. These include the authors of this paper and several staff members from the biological station. Another key is the proportion of the total number of people in the village who are involved in the activities. This proportion is relatively high for Sittee River because the number of residents is small and the activities have been diverse. This quality makes the hypercycle model especially appropriate at the village-scale of development. This scale was emphasized by Margaret Mead (1980) when she defined a village "as a community in which it is possible for every resident to know every other person living there". The opportunity exists for effective communication about conflicts, such as between ecology and economics, when the number of residents is small. In particular, vocal people who participate in multiple activities have the potential for influencing the direction of community development, for example towards sustainability. These people may provide the "social glue" that Janzen (1990) mentioned in regard to the development of sustainability in tropical villages. However, in the context of the hypercycle model, a better analogy for these people may be as social catalysts, who participate in multiple activities and attempt to influence the direction of development.

It is too soon to know if sustainability can be achieved with the application of the hypercycle model to Sittee River. Sustainable development almost implicitly requires long term commitments and the activities described above have been on-going only for about 20 years. Like some of the origin of life scenarios, chance may also be involved. Perhaps sustainability can arise in certain villages but not in others based on mixes of personality types. Certainly the balance between conservation and income generation activities will be critical for sustainability to be maintained once it arises. These issues will continue to be monitored in Sittee River to evaluate the viability of the hypercycle model for sustainable development.