Chapter 8
Resilience and Adaptation in Social-Ecological Systems

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8.1 Introduction

In most animals, behaviors are mainly encoded in the genes, but in humans, the behavioral characteristics that confer greater fitness can have a cultural nature in addition to the genetic component (Henrich and McElreath 2003; Boyd and Richerson 2006). Furthermore, the human species is the only one having developed cultural systems able to accumulate information: while many species have culture, only humans have cumulative culture. Cultural knowledge, with genetic variability, has played a major role in the adaptive strategy of human populations (Cheverud and Cavalli-Sforza 1986; Rendell et al. 2009).

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People appropriate the environment to obtain the resources that provide their livelihood. In such appropriation, human groups develop a set of knowledge and practices on the local resources that enable them to live under different conditions and environmental adversities (Berkes et al. 2000). Far from being a research topic only for scholars interested in the evolutionary process, the discussion of human adaptation to the environment is also critical in ethnobiological studies aiming to understand which characteristics favor the maintenance of practices, knowledge, values and beliefs that ensure people's livelihood in adverse contexts (see Ladio and Lozada 2008; Berkes and Ross 2013). Furthermore, the topic is even more relevant in the current context of global change, as human populations are exposed to disturbances that affect their known environmental (e.g., deforestation) and cultural orders (e.g., the presence of health centers near populations that historically have kept traditional medical systems). Such an context confronts us with the challenge of understanding how humans behave when faced with changes, either environmental or cultural. We argue that ethnobiologists can draw on a set of concepts developed in other disciplines (i.e., systems, stability, resilience, disturbance, and adaptation) to understand current human adaptive strategies.

8.2 The Concept of Systems and Its Application to Ethnobiology

The concept of system refers to a set of individual components with mutual and complementary relations capable of being analyzed by science. The components, or elements, would be the basic individual units to build a system (Odum and Barrett 2004). To facilitate the understanding of the concept of systems, we will use as an example a forest and some environmental components in it, such as nutrients and water. In the proposed example, the environmental components are plant and animal species, but also bacteria, nitrogen, phosphorus and water. These elements are connected to each other and have specific functions in the system. Functions are the activities necessary for the establishment and maintenance of a system, which can be performed by one or more components, provided that they have the basic characteristics required to perform such activities. Pollination, decomposition and dispersal would be good examples of functions performed in a forest. The decomposition of organic matter is performed by several species of fungi or bacteria because they have characteristics that enable them to perform the function "decomposition." Thus, a process can be performed by one or more components of a system.

The interaction between the components of a system ends up building additional characteristics not detectable in their individual components; these characteristics are known as emergent properties (Odum and Barrett 2004; Maturana and Varela 2007). A system combines the individual properties of its components and the additional features arising from the interaction between them. In our example, the relation between plants, animals, and nutrients, pervaded by the functions performed by each one, lead to higher-hierarchy properties that are typical of and unique to the systems as a whole, such as diversity, richness, productivity, and nutrient cycling. Such properties are different to the relation between components, as they emerge from the systemic organization.

Thus, one can consider that the system establishes functional dynamics supported by its primary functions and emergent properties. We make a distinction between structure and organization of a system. The first concept combines the processes of the system and the nominal components that perform its functions. The second concept considers only the relation of the functions performed in the systemic organization, regardless of whether they are performed by component A, B or C.

In summary, a system is recognized as a set of components that are distinguishable but interconnected by the functions they perform, so that the connections between the parts build, on a hierarchically higher and broader level, a cohesive and dynamic unit (see Odum and Barrett 2004).

All that is external to a system is called environment.[1] The type of relations between a system and its environment characterize the system as closed or open. Closed systems are completely isolated from the environment, whereas open systems influence and are influenced by the environment. Such distinction is important because the concepts of resilience and adaptation can only be applied to open systems (Trzesniak et al. 2012).

Regardless of whether a system is open or closed, all systems exhibit mechanisms that manage their functioning, or rather their stability. Such mechanisms are known as feedback loops and can be positive or negative (Odum and Barrett 2004). Negative feedbacks act to keep the system in the same regime, i.e., to ensure its order, organization, and structure. Positive feedbacks, also known as disturbances, tend to disrupt the system's equilibrium, triggering a new organization. Throughout their history, systems are affected by different disturbances, i.e., events that threaten its functioning and hence its identity. These disturbances can be physical events related to environmental disasters or climate fluctuations. Negative feedbacks deny the change of state by strengthening the system stability; in contrast, positive feedbacks promote new organizations by destabilizing the system.

Considering that ethnobiological studies seek to study the relations between human groups and their environments, one could argue that there are two systems involved: the ecological and the cultural. The ecological system consists of the natural living organisms and the relations established both among such organisms and with the external environment. The cultural system consists of human beings and the interactions between them, including the set of knowledge, practices, and beliefs developed by different human groups. Because both systems have an open nature, they strongly interact. For example, as a result of this close connection,

[1] We use the concept of environment, as understood in physics, representing all that is beyond the limits of a system and, thus, is not part of it. If the system studied is a person, then the family and social context be considered the environment. If the system is a plant fragment, all factors external to the fragment, including the people living around the fragment and that depend on it for their subsistence, are considered the environment.

there is a mutual dependency between the two systems that produces an ongoing change and, in particular, an adjustment between their structures and their organization, thus indicating a coevolutionary relation between them. This interaction is so strong that, according to some researchers, is more appropriated to refer to a social-ecological system, rather than to two separate systems (Berkes and Folke 1998).

We argue that the concept of social-ecological systems could be useful in ethnobiology. To explore the argument, we use the example of a local medical system. A local medicinal system is a system composed by people of a given social group and plants with therapeutic potential. Both components have their intrinsic, and thus individual properties, however, these components interact through different functions. For example, people manage the landscape, building backyards and vegetable gardens, which are important places for the cultivation of medicinal plants. This management should be understood as a function performed by people that connect them with the plant resources. In turn, plants have potentially therapeutic properties, such as a "curing diseases of the gastrointestinal tract" or "curing worm infestations." Let us consider the need to cure the flu as the function "curing the flu." Plants such as "spearmint," "peppermint," "lemongrass," and "lemon balm" can potentially perform this function, either individually or together in a single preparation. The function will only be performed if there is an element with the basic characteristics necessary to do so. In any time interval, the local medical system, of which both people and plants are components, will have a specific equilibrium state, organization and structure. Negative feedbacks, such as beliefs that will reiterate local practices, and positive feedbacks, such as the emergence of new diseases, can affect the structure of the local medical system.

To understand what local medical systems represent, we assume that -throughout human history—diseases have influenced the structure and evolution of cultures, acting as important forces in natural selection in the sense that many cultural characteristics are adaptive responses to disease prevention and treatment (Dunn 1976; Brown 1987). Accordingly, human groups have built medical systems formed by a set of concepts and practices regarding health and disease in which the perception of diseases and customs are connected to the chosen treatment strategies (Jain and Agrawal 2005). These systems bring together local perceptions of disease causes, the recognition of the symptoms of different diseases by the human group, and the strategies and alternatives for their treatment, including the set of elements used in the healing process (i.e., plants, animals, etc.), in addition to the evaluation of the results of each of the treatment strategies available (see Kleinman 1978; Bhasin 2007).

While not having a strictly physical nature, the social-ecological systems are considered as open because they are strongly influenced by the environment. For example, in a situation of resource shortage, a certain local community can suffer pressures due to the absence of basic elements for survival. However, people being affected by resource shortage may use different management strategies to adjust the environmental context to their demands, i.e., they may use different strategies to deal with pressures (see Berkes et al. 2000; Walker and Salt 2006; see also on this book, the chapter on the niche construction theory).

8.3 Understanding the Classic Concepts of Resilience

The term resilience is used in many different areas of knowledge with, mainly, two different understandings. The first understanding of the concept of resilience considers that there is an overall stability that the system must achieve to remain resilient. The second understanding considers that there are multiple stability states, or regimes, and the system can achieve different configurations within the same regime. When we refer to regimes, we are addressing a range of states in which a system can exist, reaching or failing to reach an equilibrium state. This range is defined by the variables and processes that control the system (Gunderson 2000). For example, a semiarid forest region can be deforested and used for agricultural activities. At first, it is possible that, once agricultural uses are abandoned, the forest regenerates and the area returns to its regime. However, if the agricultural activity leads to soil exhaustion, the region may suffer a process of desertification and never return to the forest state. In this situation, the area would be reorganized into a new regime, in this case formed by few species tolerant to this desert condition (see Gunderson 2000, for more examples).

Thus, the basic difference between the two understandings of resilience is that the first assumes the need for stability, while the second assumes the existence of multiple regimes with different stable states. Within the framework of the first understanding, Pimm defined resilience as "How fast the variables return towards their equilibrium following a perturbation" (Pimm 1984:322). The advantage of this definition is that resilience can be measured as the time required for the system to return to equilibrium, and this measure can be scaled in time units.

The second definition assumes that a system can constantly change and may rarely achieve an equilibrium state. According to these assumptions, a system may exist in several regimes, not necessarily reaching a permanent equilibrium state. Resilience is defined as "the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks" (Walker et al. 2004:2). In other words, a system is more resilient the greater its capacity to absorb disturbances, and the system vulnerabilities would be related with its transition to another state.

Notice that the concepts of stability and resilience are different. A system can be considered stable when it is either in equilibrium or near an equilibrium state. In other words, the less fluctuations occur in a system, the greater its stability is (Holling 1973). According to the second understanding, a system can be resilient, even if it is not stable.

Which of the two definitions of resilience best applies to the study of social-ecological systems? Given that ecological systems are essential constituents of social-ecological systems, it seems reasonable to assume that the ecological definition would fit the purpose better. Thus, we will use the notion of resilience linked to the existence of multiple stable estates.

Although the most popular concepts of resilience previously discussed bring to light its conservative character (i.e., of absorbing disturbances while maintaining its original function), the study of social-ecological systems has suggested a new way of viewing resilience that is related to the capacity of renewal, reorganization and the development of these systems (Folke 2006). According to this logic, in a resilient system, disturbances have the potential for creating opportunities and innovations (Folke 2006). Therefore, depending on the perspective adopted, resilience can indicate either a system that maintains its characteristics and properties upon facing a disturbance, or the capacity of that system to transform itself, thus completely changing its characteristics (Walker and Salt 2012). This latter system strategy is known as transformability. Both strategies can lead to an adaptation of the system to the disturbance conditions.

When addressing the concept of resilience in the sense that the system absorbs disturbances, we are not claiming that the system does not undergo any changes: there are changes, but they occur within the limits that allow the maintenance of the system in a given state. In this case, in addition to transformability, there are other system properties that can favor resilience because they represent the responses of the system to disturbance, such as flexibility and adjustment. Flexibility and adjustment are related to the number of possibilities that a system has to respond to a disturbance, thereby increasing the range of choices and potential solutions which prevent the system from losing its functional identity, thus favoring resilience (see Walker and Salt 2012). The following study exemplifies how resilience and flexibility can be applied in social-ecological systems. Over time, farmers of the Iberian Peninsula have incorporated commercial varieties of cultivated plants at the same time that they continue to grow local varieties that are part of their tradition. In this case, people who hold a high knowledge of the commercial varieties also have greater knowledge of local varieties (see Reyes-García et al. 2014). This example illustrates that information on both commercial and local varieties is not mutually exclusive and suggests that the knowledge systems of these farmers has been resilient by incorporating changes (i.e., commercial varieties) while simultaneously keeping the knowledge associated with local varieties (Reyes-García et al. 2014). Furthermore, this situation may also promote the resilience of the social-ecological system by increasing the flexibility of responses to future disturbances as farmers hold knowledge of both commercial and local varieties to which they can resort to in times of crisis.

8.4 The Interpretations of Resilience in Ethnobiological Studies

Ethnobiological studies have the potential to contribute to the understanding of the characteristics that could lead to resilience of social-ecological systems. However, the notion of resilience can be interpreted in different ways in ethnobiological studies. We separated these interpretations into three basic sets. To illustrate them, we will use again the example of a local medical system.

8.4.1 Structuralist Interpretation of Resilience

According to this interpretation, disturbances that cause major structural changes would entail the loss of resilience and the system's transition to a new regime. Such an interpretation does not take into account the assumption that, for the system to change its identity, it needs to suffer functional changes. However, despite its apparent disagreement with the classical concepts of resilience, this interpretation can be implicit in ethnobiological studies, as in studies that attribute the loss of resilience of a local medical system to the introduction of exotic species or allopathic medicines.

8.4.2 Functionalist Interpretation of Resilience

According to this interpretation, for the system to continue under a regime, its functions need to be maintained, even if there are strong structural changes, i.e., in the system components. To illustrate this idea, consider that our hypothetical local medical system has ten species that are used by the community for the treatment of headache and, consequently, that these species share the same function in the system: "to treat headaches." If any disturbance, such as deforestation, leads to the disappearance of a species in that category, people can use the other species to accomplish the function of the lost species (see the chapter of this book about utilitarian redundancy). This characteristic demonstrates its flexibility, which favors its resilience (Ladio and Lozada 2008). In this case, the system could absorb disturbance without changing its functions, i.e., its identity, although the system also suffered changes in the number and composition of the species. With this hypothetical example, and according to the functionalist interpretation, we can say that the local medical system based on the use of plants was shown to be resilient upon the disturbance. However, for the functionalist perspective (which mainly focus on the maintenance of the system's functions), discontinuing the use of plants while incorporating the use of allopathic medicines would not lead to another stable estate, because the main function of the system (i.e., the treatment) would still be guaranteed.

8.4.3 Processual Interpretation of Resilience

This interpretation represents a compromise between the two interpretations above. On the one hand, structural changes would not be sufficient for the loss of resilience and to the entry of the system into a new regime. On the other hand, maintaining the system functions would also not be sufficient to ensure its resilience. To avoid changes in the system's regime, in addition to its functions, the system must retain the processes governing them. In the previous examples, the loss of one species to treat "headache" would not lead to loss of resilience because the function of the system was maintained and it would still be governed by the same processes based on the traditional concepts of health and disease in its methods of diagnosis, the selection of products (such as plants) for treatment, etc. Even the introduction of allopathic medicines in the system would not necessarily lead to the transition to a new regime. The coexistence of traditional and western medicine could also keep the system in the abovementioned regime, provided that the functions of the system were not changed and that the processes that govern it would remain the same. According to this assumption, a complete replacement of the plants by allopathic medicines could even occur if the processes were maintained. However, the introduction of western medicine in a local medical system might eventually change the processes governing the system. The predominant factors that once included the transmission of knowledge, experimentation, and, occasionally, rituals and beliefs related to the cure might be replaced by the search for a doctor who prescribes medicines based on biomedical concepts typically external to the society. According to the processual perspective, the introduction of allopathic medicines would not necessarily lead the system to a new regime.

8.5 Factors that Can Interfere with Resilience: Analysis Based on Ethnobiology

The ethnobiological literature still tends to address the topic of resilience only superficially, theorizing about its concepts and its importance, without actually mentioning the factors that increase resilience and the factors that can led a social-ecological system to shift regimes. Below, we suggest some factors that can interfere with the resilience of these systems and that—therefore—deserve special attention.

8.5.1 Utilitarian Redundancy

The concept of utilitarian redundancy is based on the assumptions of functional redundancy in ecology, which establishes that several species can perform the same function in an ecosystem (Walker 1992; see also the chapter on redundancy on this book). Thus, when a disturbance occurs, each species may respond in different ways, being more or less vulnerable. This diversity of responses contributes to the resiliency of the ecosystem. Thus, the utilitarian redundancy of a system relates to the number of species that share a particular utilitarian function in a social-ecological system, i.e., that are used for the same purpose (Albuquerque and Oliveira 2007). Thus, the higher the utilitarian redundancy in a social-ecological system, the greater the flexibility of a system, and the greater its resilience, given that the loss of a species would not bring great damage to the system as others could replace it.

8.5.2 Transmission of Knowledge

One of the major pillars of the maintenance and diversification of social-ecological systems is the transfer of information. Thus, the exchange of information among members of a community is expected to affect the system's resilience. This consideration suggests that a high utilitarian redundancy does not necessarily favor the resilience of a social-ecological system if this redundancy is not shared among the social actors (Ferreira Júnior et al. 2013). We can illustrate this idea based on a hypothetical community in which the knowledge of certain practices involving natural resources, at a given point of time, is restricted to only one person. Thus, if such a person dies before having transmitted such information, this loss will affect the resilience of a system, as it will not be available when needed.

8.5.3 Symbolic and Cultural Aspects

Frequently, the capacity of a system to resist disturbances (e.g., changes resulting from urbanization processes) also depends on cultural and symbolic factors related to the elements, processes, and functions of the system. Certain communities do not accept different cultural practices simply because they do not believe in the assumptions that support other cultures. For example, Medeiros et al. (2012) found that, despite establishing an intimate contact with a new environmental context, some migrants maintain their traditional medical system, which forms part of their cultural identity. In contrast, the influence of the media and increasing urbanization leads other communities to adhere to new medical systems due to the often-disseminated notion that plants “do not cure” or are less effective than biomedical treatments. Thus, the same disturbance may have different effects in different systems, depending also on the social representations and symbols.

Recently, some ethnobotanical studies have applied resilience concepts to understand some aspects of the relation between people and plants. For example, the strategies adopted for the use of medicinal plants in the communities of Patagonia, Argentina, involve the use of medicinal plants from diverse environments. Such practice relate to the migration of these communities when families travel with cattle to different grazing areas. These travels can promote the resilience of local systems by increasing the system's flexibility in the use of medicinal plants from different environments (Ladio and Lozada 2008).

8.6 Adaptive Processes of Social-Ecological Systems

Adaptation is related to characteristics that provide advantages for a population, leading to increases in what is known as adaptive fitness. In biology, this increase in fitness is understood as an increase in the number of fertile descendants over time (see Jeanne 1998). However, this concept does not imply that adaptation is a modification or response perfectly suitable to the environment, but that is an appropriate modification to circumvent environmental problems, weighing costs and benefits in an environment undergoing rapid and continuous changes (Dunn 1976; Wiley 1992). However, from a cultural viewpoint, not every change leads to increased fitness, as they can instead promote some other advantages.

One of the key biological phenomena to help us understand the evolution of the cultural component in humans is phenotypic plasticity. The phenotype is the expression of a genotype as a result of the environment in which it develops. A phenotype may be rigid in its expression (e.g., two eyes, one nose) or flexible (blue eyes), depending on the environment in which it develops. In this case, cultural choices can be understood as flexible features since the practices of a human group can be adjusted to meet environmental demands, such as climate changes. This flexibility was a step in human evolution that allowed the development of multiple behavioral possibilities in several circumstances of our lives. Culture, therefore, which is a result of evolution, is essential to the human condition.

An important characteristic of social-ecological systems which can be understood in light of these adaptive processes, is Traditional Ecological Knowledge (TEK). According to Berkes et al. (2000), TEK can be defined as a set of knowledge, practices, and beliefs about the environment that is cumulative over generations and dynamic and flexible in face of the fluctuations of that environment. The cumulative and adaptive character of this knowledge system allows people to adapt to the environments where they live (see Berkes et al. 2000).

The adaptive characteristic of cultural systems is based on the statement that beneficial environmental information passes from generation to generation, creating what is known as cumulative reservoirs of adaptive information, where human populations store the best efforts of the minds of previous generations (Boyd and Richerson 2006; Henrich and McElreath 2003). In addition, information that assures greater fitness is preferably transmitted through a cognitive process known as adaptive memory (Nairne et al. 2008; Nairne and Pandeirada 2008; Nairne 2010). An example of this TEK property can be found in the difference between "knowledge" and "actual use," as people do not necessarily use all resources stored in memory. According to this distinction, the group of species referred as known, but not used by a community, is designated as "stock knowledge." The species that are actually used are recognized as "mass knowledge" (Albuquerque 2006). From an evolutionary viewpoint, the stock knowledge may be a strategy of local populations to ensure the existence of alternatives that can help them meet their needs if some resource is extinguished locally. In the event of a disturbance that threatens the availability of "mass" species, the "stock" species would assume the function of the firsts, thus entering the domain of the currently used species. The use of such species would therefore allow to maintain the local system, in this case the use of medicinal plants, functioning. In sum, stock knowledge increases the resilience of the local system because it enriches the utilitarian redundancy.

Another example that can indicate the adaptive nature of cumulative knowledge relates to the process of choosing species for medicinal use. Through experimentation, often by trial and error over generations, people select species for the treatment of diseases (Dunn 1976). The knowledge that a plant is useful in the treatment of some disease is not encoded in the genes; new generations will learn this information through cultural transmission mechanisms (Henrich and McElreath 2003). Thus, in local medical systems, species are selected for medical use based on criteria that are passed down through generations. Moreover, some of such criteria can be found in several places across the world. Thus, many human groups select plants based, for example, on their organoleptic properties (Brett and Heinrich 1998; Ankli et al. 1999). The medicinal plant selection criteria may have been subjected to natural selection so that different cultures could recognize and select medicinal plants for the treatment of diseases over different generations (see Johns 1990). For example, people from different societies seem to identify medicinal plants based on their effectiveness. One study showed that different communities of Nepal, New Zealand, and the Cape region in South Africa treat the same therapeutic conditions with phylogenetically related species. Although the species used in each region are different, people select evolutionarily related species for the treatment of the same diseases in the three regions studied. More importantly, the groups of related plants are those that exhibit higher numbers of species with biologically proven active principles (see Saslis-Lagoudakis et al. 2012). Another example is found in the inclusion of exotic species in traditional pharmacopoeia. The diversification hypothesis attempts to explain this phenomenon by affirming that, over time, people included exotic species in medical systems to fill therapeutic gaps (Albuquerque 2006; Alencar et al. 2010). This behavior would ensure that the exotic species enter the pharmacopoeias to diversify the treatment repertoire, thus gaining important adaptive value for these populations because they can increase the possible options for disease treatment.

Even when the exotic species are included in local medical systems to replace the uses of native plants (rather than to diversify the system), their entry may represent an adaptive character of these systems. What is often seen as erosion of traditional knowledge systems can indeed indicate a choice based on the adaptive advantages of some exotic species (such as greater efficiency, increased palatability, smaller distances for collection, etc.). Under this perspective, if—in a given medical system—replacement of native species by exotic ones occurred, such replacement could be due to the fact that the exotic plants had higher benefits for that local population than the native ones. This, however sets a future threat: What if, in the future, people need native plants, but the knowledge about them is already lost? Although we should acknowledge that this loss can happen, we need to avoid assigning positive or negative values to adaptive choices, as such losses are inherent in the evolutionary process (see Gómez-Baggethun and Reyes-García 2013 for an example with knowledge systems). Thinking from the perspective of biological evolution, a population can evolve to exhibit features that are advantageous for a particular environmental situation, however, if new drastic changes in environmental conditions occur, the characteristics obtained through evolution may no longer be useful or desirable, thus generating new evolutionary pressures.

Moreover, local practices can also change the environmental selective forces, acting on human groups and, consequently, in cultural systems (Wiley 1992). In a way,

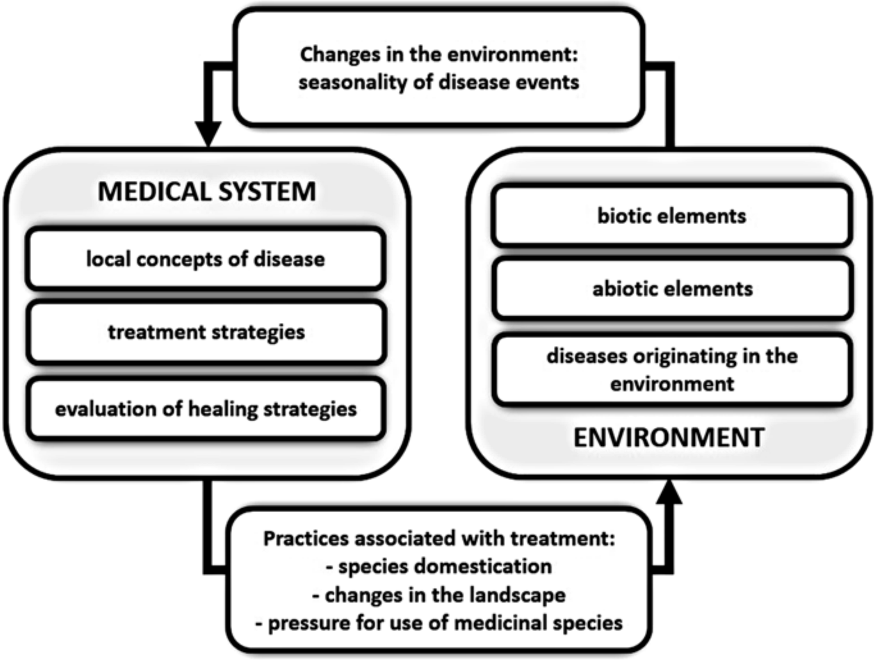

Fig. 8.1 Diagram showing the interrelation between a medical system and the environment in which it is placed. The diagram shows how medical systems, formed by a set of local concepts of diseases associated with treatment strategies and evaluations of therapeutic practices, may change environmental landscapes through the selection and use of medicinal species over time. The environment is represented by biotic and abiotic elements, which can be interpreted as disturbances of the medical system. Over time, certain changes in this environment, such as climate change and the very local practices that alter the landscape, may favor the emergence of diseases (i.e., disturbances) and, thus, influence the behavior of medical systems

as in the overharvest of local medicinal plants or in the plant domestication (Monteiro et al. 2006; Albuquerque and Oliveira 2007), local practices may change environmental landscapes and the selective forces acting on either the resources used or even the people themselves. Figure 8.1 shows this interrelation using the example of a medical system and the environment with which it interacts. We can use the niche construction theory as an example of a theoretical framework that evaluates the modification of environments by organisms from an evolutionary viewpoint. This theory takes into account the organisms' capacity to modify the environment on which they depend to the point of changing the evolutionary pressures, favoring the selection of advantageous traits for the propagation of their own species (Laland and Boogert 2010). For example, in the process of species domestication, human groups have selected, over time, characteristics of species to meet their needs to the point that current plant species show morphological changes to suit human dietary preferences (Parra et al. 2012).

8.7 Final Considerations

The previous explanations make clear the complexity of studying resilience and adaptation in social-ecological systems. To date, one of the main setbacks in the study of resilience is that it cannot be directly measured. The resilience of a social-ecological system can, however, be inferred indirectly by the evaluation of the system characteristics. With such premise, we suggest some questions that can guide future research:

1. What are the main strategies present in social-ecological systems that allow them to deal with disturbances? From the ethnobiological studies analyzed, we can identify two main types of disturbances. The first disturbance refers to processes that affect people and their cultural systems, such as diseases that threaten the health and well-being of people. The second disturbance refers to processes that affect the environment, including human-induced change, leading to the decrease of available functional species in a system. In face of these disturbances, which strategies are selected by different groups of people to increase the flexibility of their social-ecological systems? Redundancy can be one of the methods in a situation in which a certain community introduces exotic species into their pharmacopoeia as a strategy to increase the flexibility of functions with few functional analogues.
2. In addition to disturbances affecting the cultural systems mentioned above, there could be a wide variety of disturbances that affect a community to which the researchers do not have direct access by observation. It is therefore important to assess what do the local people identify as the main disturbance that affects the resilience of their social-ecological system? Focusing on local strategies formulated to address what people themselves consider as disturbances may help to elucidate important characteristics about their resilience and may assist in the design of governmental strategies for biocultural conservation.
3. Considering the work already performed, to the best of our knowledge, there are no studies that evaluate the effect of a disturbance on the different functions of a knowledge system. If we know that uses of natural resources can have different characteristics, can functions be maintained in the system by distinct mechanisms upon facing the same disturbance? To observe this phenomenon, it is necessary to understand that disturbances may affect different functions, as for example would occur if few species were inserted in different utilitarian categories.

In this chapter, we discuss the roles that some concepts developed in biology can play in understanding dynamics in social-ecological systems. In addition to redundancy, environmentalists have used the concept of functional diversity as one of the characteristics for the stabilization of ecological systems in their environments. Thus, when comparing local communities in different systems, which environments would favor the appearance of greater diversity of function and utilitarian redundancy? To answer some of the above questions, long-term investigations are needed.

Ad-hoc studies, with very small time scales, make it difficult to infer results about resilience mechanisms in social-ecological systems. Although this limitation does not impede the studies, it hampers the interpretation of the phenomena.

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