1 Introduction

The natural world is overstressed and degraded by growing human intrusion into the majority of ecological processes, reducing their effectiveness (Crutzen & Stoermer 2000). Also, as an agent of ecosystem services, "nature" is not fully represented in human social and cultural contexts dominated by economic and political priorities. Human considerations amount to a diffuse underestimation of life's processes in the entire Earth system, and thus cause weakness in human strategies for preserving natural resources and biodiversity, maintaining ecosystem services, and finally assuring a satisfactory level of well-being to all human societies for the long term.

To try to remediate and reduce this cultural gap, I propose a narrative based on the spirit of Descartes's *catena scientiarum* (Foucher de Careil 1859–1860) in which well-explained rules could identify specific scientific elements to form a shared human understanding. This Element therefore aims to develop a coherent set of ecological and semiotic theories and principles focused on landscape as a fundamental dimension in which environmental and human processes can find coherent life strategies. In particular, this effort offers a reasoned guide to theories, principles, and models that have been proposed recently by scholars from disciplines ranging from ecology, to biosemiotics, ecosemiotics, landscape ecology, and conservation biology as an epistemological model to be placed side-by-side with humanities like anthropology, archeology, history, etc. (Figure 1).

The main arguments to be discussed are:

Complexity (Section 2): Complexity is a universal paradigm that results from interactions of a plethora of abiotic and biotic processes far from equilibrium. These are statistically highly improbable and generate a condition of apparent slowdown of the entropic disorder that Schrodinger (1944) called negentropy, rich with surprise and information (Lloyd 2007). Complexity is the humus on which life blooms, evolves, differentiates, and eventually suffers from extinction in some particular traits and organizational forms. Complexity is necessary to assure continuity for every life form and their functional assemblages on the Earth. At the same time, intra- and interspecific interactions feed turnover and evolution in the composition of biological assemblages.

Uncertainty (Section 3): Uncertainty is a characteristic of the universe that every species must face. It means that unexpected events can occur at any time and cause the possible incapacity of a species when it is exposed to previously unknown risks. At the same time, uncertainty can stimulate processes/mechanisms of adaptation.

Information (Section 4): If complexity is a property that emerges from aggregation and organization across spatial, temporal, and functional scales of organisms, its quantification is represented by the amount of information expressed by the system. Thus, information is the currency exchanged between organisms and their aggregations/assemblages.

Some ecological paradigms (Section 5): The role of ecological paradigms is of first magnitude in my discussion and in particular will be presented using r/K strategies of selection by organisms for survival (Pianka 1970), the source-sink model (Pulliam 1988), and ecological niche theory (Hutchinson 1957). These paradigms have an ecosemiotic counterpart and therefore create the necessary background for an ecosemiotic theory.

The Landscape dimension (Section 6): In the present narrative we consider the landscape as the phenomenological context, the common arena or container in which complexity emerges and differentiates. Landscape is a perfect candidate for this role because it is the spatial, temporal, and cultural context in which different agents (humans, animals, plants, bacteria, viruses) find real possibilities to deeply exchange information with abiotic life support and biotic assemblages. Given that no organisms can escape the perceptive/semiotic mechanisms that link the individual to its surroundings, the concept of landscape is implicit in the definition of life (Barbieri 2008). In particular, the decision to use landscape as the phenomenological context for connecting ecological and semiotic principles is encouraged by the universality with which the landscape processes are considered by all organisms.

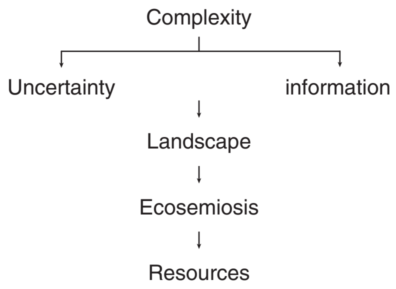

Figure 1 – The main ingredients of landscape ecosemiosis, where Complexity is the main character of systems, include Uncertainty as the constraint that the organism faces, Information as the currency exchanged between the system and organisms for maintaining an active channel of communication, and Landscape as the physical and cognitive spatial dimension. Ecosemiosis is the process of signification, and Resources are material or immaterial entities that nourish life's autopoiesis.

The landscape dimension is based upon the principles of landscape ecology, a relatively young discipline that has gained great popularity since the 1980s (Wu & Hobbs 2007). The multiplicity of visions that have been presented in this discipline pose serious problems of synthesis between different paradigmatic approaches ranging from geographical to semiotic perspectives (Lindstrom et al. 2011).

A general theory of resources (Section 7): After the description of the salient qualities of a landscape, the general theory of resources seeks to explain how resources are necessary for autopoietic processes, i.e. reproduction and self-maintenance. The particularities and role of resources for organisms are obvious, as they represent the necessary fuel for life (Varela & Maturana 1980).

Elements of ecosemiotics (Section 8): "Ecosemiotics studies the role of environmental perception and conceptual categorization in the design, construction, and transformation of environmental structures"(Maran & Kull 2014). Ecosemiotics is the use of a zoosemiotic paradigm that has its fundamentals in biosemiotics, in communication theory, and in animal behavior (Maran et al. 2011, 2016).

We propose that ecosemiosis can function as an intellectual bridge between divergent sciences to incorporate within a unique framework different paradigms born of separate perspectives (Eder & Rembold 1992), and to demonstrate the efficiency and utility of an approach that assures connectedness among signals from different sources.

Ecosemiosis is at the basis of food chains, connecting species to their environments by semethic (semion-sign and ethos-habit) interactions, establishing "personal" reciprocal knowledges among different organisms as they communicate in particular situations (Hoffmeyer 2008, p. 189). Ecosemiosis is responsible for environmental changes produced by these creatures according to their specific sensory abilities.

Human culture is an important agent in these ecosemiotic processes by increasing knowledge between species. However, paradoxically, the diversity that results from communication processes that can accommodate species in close ecological spaces together, may become a risk because of too many communications, or too much noise (Kull 2005).

Fundamentals of ecoacoustics (Section 9): Recently the role of sounds in ecological processes has been emphasized on a theoretical basis in ecoacoustics (Farina 2018a). Sound is a semiotic tool for communication between individuals and species, for navigation (especially in the absence of light), for performance of reproductive behaviors, and for transmission of cultural messages. Soundscapes are the emerging acoustic characteristics of landscapes and impart complexity to environmental systems.

Cultural landscapes (Section 10): Recognizing some landscape configurations as the result of cultural human stewardship associated with historical processes places cultural landscapes in a privileged position. Cognitive, cultural, and spiritual qualities enrich the signs that emerge from landscape. Cultural landscapes maintain a high level of biodiversity resulting from long-term coadaptation of humans with other living beings and demonstrate how the integration of separate concepts as those above is guided by a thinking rooted in the humanities (Smith 2014). A serious attempt to bring natural processes – especially ecological processes – within the purview of the humanities is an activity absolutely necessary to assure the durable and sustainable development of human societies (Eder & Rembold 1992). A new ecosemiotic framework, powered by an integrated epistemology, can forestall a planetary catastrophe created by development based on the doctrine of necessary continuous increase of gross production and from which evident signs of ecosystem degradation and biological impoverishment are growing at an alarming frequency (e.g. Hallmann et al. 2017, Lister & Garcia 2018, Sanchez-Bayo & Wyckhuys 2019). Such ecosystem degradation is also associated with the growing difference of well-being between poor and rich societies and countries.

2 Environmental Complexity: An Ecosemiotic Vision

2.1 Synthesis

Complexity is an emergent property of environmental systems and is associated with their order, diversity, and resilience. Recent human intrusion reduces complexity and thus puts many life forms at risk and compromises human well-being.

Although complexity is an elusive concept, it characterizes the majority of physical, biological, economic, and social systems. It manifests itself at every level of hierarchical scale by which we perceive and describe our known universe. Complexity emerges at the border between different levels of organization and has been compared by Lloyd (1990) to a firebreak that retards the inexorable thermodynamic dissolution of the world.

Complexity is the result of interactions between different scaled systems either in the macrocosm or in the microcosm; energy, matter, and information are its fundamentals. Environmental complexity emerges as a property from intra- and interspecific interactions between individuals, species, and their assemblages, occurring along a broad range of temporal, spatial, and functional scales (Figure 2).

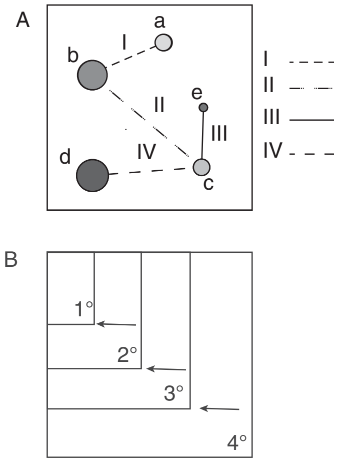

Figure 2 – Schematic representation of complexity: (A) Complexity is created by reserved relationships between different objects (a,b,c,d,e) with a distinct typology of interactions (I,II,III,IV); (B) Complexity emerges at the border between different scaled systems; here are represented four systems inside a hierarchy.

Environmental complexity is the result of the stability, resilience, and diversity of every organized system (Fraccascia et al. 2018, Siegenfeld & Bar-Yam 2019). Complexity is not a self-explicative, visible character; it requires a multidisciplinary approach to be perceived, identified, and finally interpreted (Lewin 1999). Complexity cannot be gauged as an absolute value, but instead by comparing systems with differing levels of organization. An impressive literature around this concept puts the evidence on different systems hierarchically organized. Complexity may be considered a kaleidoscope paradigm because at a micro-level it appears as intricate multifactor relationships, but scaling up, at a macro-level systems seem to respond to a lower number of variables.

The tools for guidance across this scenario are based on the capacity of an observer to intercept and elaborate “the messages” that every life form directly, and the physical contexts indirectly, continuously scatter around. In every system, individual species have a deep exchange of signals with other communicating subjects (Bradbury & Vehrencamp 1998). The quality and quantity of such signals assure their survival or decree their extinction. But a paradox of this paradigm is that the incommunicability between organisms and between systems contributes to complexity and maintains the functionality of ecological systems (Gell-Mann 1995, Gell-Mann & Lloyd 1996).

The human role as environmental keystone species has enormous influence on political, economic, and social decisions that affect the Earth’s fate, and thus