Complex Species: from Colony Communication Networks to Patterns

M. Convertino\textsuperscript{a,b,1}, P. Borgogno\textsuperscript{c}, B. Morel\textsuperscript{d}, I. Linkov\textsuperscript{b,d}

\textsuperscript{a} Department of Agricultural and Biological Engineering-IFAS, University of Florida, Gainesville, FL, USA

\textsuperscript{b} USACE Engineer Research and Development Center (ERDC), Risk Modeling and Decision Science Area, Concord, MA, USA

\textsuperscript{c} Politecnico di Torino, DITIC, Torino, Italy

February 23, 2011

\textit{Keywords:} species, patterns, communication network, cost of communication, resilience, optimization.

A novel species communication network model mimicking the signaling among nearest-neighbors colonies is proposed. Species colonies are considered as particles and the colony generation is modeled as a sequential growth process. Vegetation was considered as our case-study. We schematize single-species colonies as nodes and the signaling among nearest neighbors colonies as links. Individuals communicate only with nearest neighbors within a colony. We believe that the maximization of a foraging-dispersal function under the constraints of the initial environmental stress and of the domain geometry can determine the formation of the observed patterns. For low soil porosity of the substrate the patterns can be generally described by a combination of only the intra- and inter-generation spacing that are a function of the diffused environmental stress (e.g. decrease in soil moisture and/or soil nutrients, and increase in grazing). It is unclear the origin and number of the possible unstable patterns for medium/low and very low environmental stress. The box-counting revealed a self-similar behavior of vegetation patterns (random and deterministic) for the whole range of environmental stress analyzed. We suggest the fractal dimension as pattern stability indicator measuring the degree of optimized arrangement of species colonies. We introduced the concept of cost of communication for characterizing the resilience along an environmental stress gradient. The triangular-motif communication network is not characterized by the lowest cost of communication during the pattern generation, however it exhibits the lowest cost of communication in the colony re-generation after random and targeted attacks (e.g. colony death after localized environmental stress). The most resilient colony pattern arises from the most resilient communication network topology. In the case of high soil porosity a DLA “scale-free like” and a fully connected random communication networks appear for high and low environmental stress respectively. We believe in the generality of the model that can be applied also to very dynamical systems for example to bird colonies and social groups.