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Similarity analysis of macro- properties of ecosystems and thresholds for life

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Inspired by Lovelock's conjecture [1] that "lifelike processes [might] require a flux of energy above some minimal value in order to get going and keep going" we use formal dimensional analysis to determine the macroscopic parameters that constrain the level of complexity that an ecosystem can support. We perform a bottom up analysis of an idealized ecosystem to establish the general organising principles that apply to physical variables for ecosystem function, and how they are related to each other. Ecology characterizes the level of ecosystem complexity by observational methodology which differentiates different functional groups of individuals within the ecosystem. This categorization yields intrinsic macroecological variables such as density, diversity, trophic level, metabolic rate and body size along with characteristic lengthscales for clumping or dispersal of individuals. In nature, macroecological patterns are found between these intrinsic macroecological variables, and with extrinsic variables such as habitat size and the rate of supply and uptake of resource. Our starting point is that these patterns have a fundamental physical constraint- that individuals in the ecosystem can only, in sum, utilize resource at the rate at which it is taken up by the ecosystem as a whole. This constraint corresponds to an ecosystem which is dynamically balanced, that is, it can respond to exogenous change with endogenous reconfiguration such that the balance between the net rates of uptake and utilization is on average maintained. On this basis we use similarity analysis to determine the relationship between macroscopic ecosystem parameters and we show that this reflects macroecological patterns observed on earth. This then yields a control parameter which constrains how complex an ecosystem can be- thus we can identify and parameterize thresholds in the ecological complexity of the system.

[1] Lovelock, J. E., Gaia, A new look at life on Earth, 1979. Oxford University Press.