Diving into complexity: exploring fractality in seabird foraging behavior

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Animal behavior is organized to optimize biological interactions, including those relevant to foraging, mating and avoiding predators. Recently, animal movement has been likened to theoretically optimal search algorithms such as 'Lévy motions', which are self-similar and super-diffusive movements in which small- and large-scale movements are linked through a common scaling (power law) relationship. Much work has now gone into characterizing these complex and anomalous movement patterns in observed data (Viswanathan et al 2011; Reynolds 2015), but there has been little emphasis on the degree to which factors both intrinsic and extrinsic to the animals might affect their emergence. That said, parallel research on fractal scaling in times series of animal behavior has shown clearly that stress, disease or other challenges disrupt behavioral patterns and thereby cause reduced efficiency in behavioral performance: so-called '*complexity loss*' (MacIntosh 2014). Evidence is also accruing to suggest that environmental heterogeneity can induce changes in the complexity signatures of individual animals. Yet, the relative importance of intrinsic versus extrinsic sources of variation in complexity signatures remains an open question. Here, we explore the possibility that complexity signatures derived from animal behavior time series can be used as indicators of both animal and environmental conditions, towards enhancing the extent to which mesopredators such as penguins can act as eco-indicator species (Figure 1). We hypothesize that certain complexity ranges signify optimal patterns of behavior (Figure 2), and that conditions forcing animals outside of this range may have fitness consequences. Focusing mainly on two species of penguin, the little penguin (*Eudyptula minor*) and the Adélie penguin (*Pygoscelis adeliae*), we show first that different stressors can cause variation in complexity signatures (Figure 3) and second that complexity signatures are dependent on certain features of the environment. We close with a comparative analysis of over a dozen penguin species aimed at disentangling the relative contributions of phylogeny and the current environment toward generating observed complexity signatures.

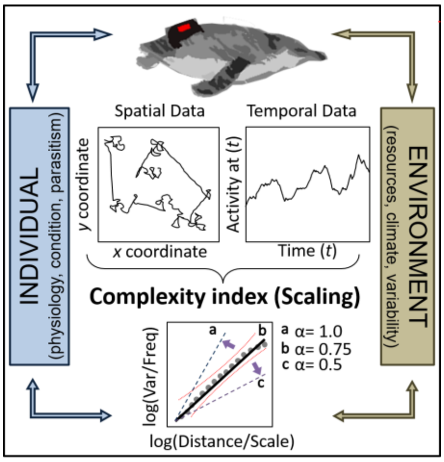

Figure 1. Towards a generalizable index of complexity as an indicator of animal-environment interaction.

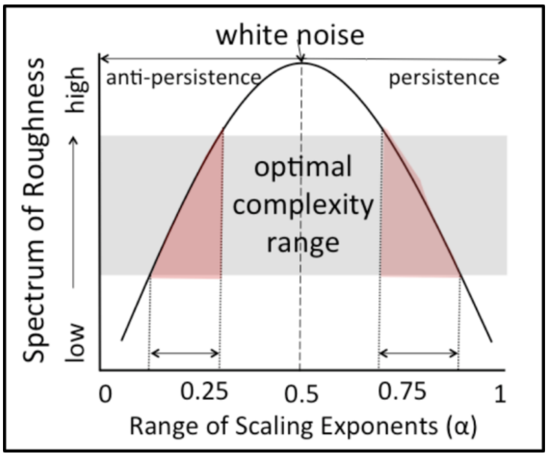

Figure 2. Theoretically optimal complexity ranges along a gradient of behavioral '*roughness*'.

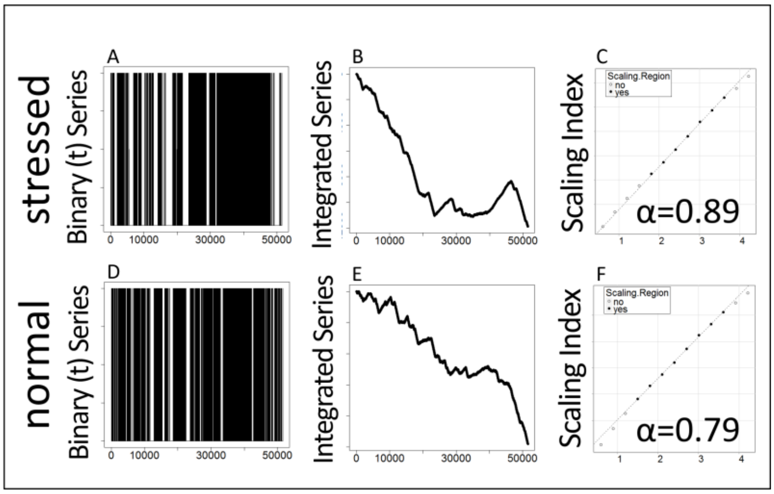

Figure 3. Fractal scaling as an index of complexity in animal behavior under stressed and normal conditions. (A) Binary time series reflecting a sequence of diving and surface time. (B) Integrated (cumulatively summed) time series reflecting behavioral walks. (C) Double logarithmic plots of fluctuation in dive sequences as a function of measurement scale: α-exponents reflect complexity signatures.

References

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