



Show me chaos! seeking fractal time in the behavior of indicator species

Andrew MacIntosh^a, Xavier Meyer^{a,c}, Andre Chiaradia^b, Akiko Kato^c, Yan Robert-Coudert^c
^a Kyoto University; ^b Phillip Island Nature Parks; ^c CNRS

the background

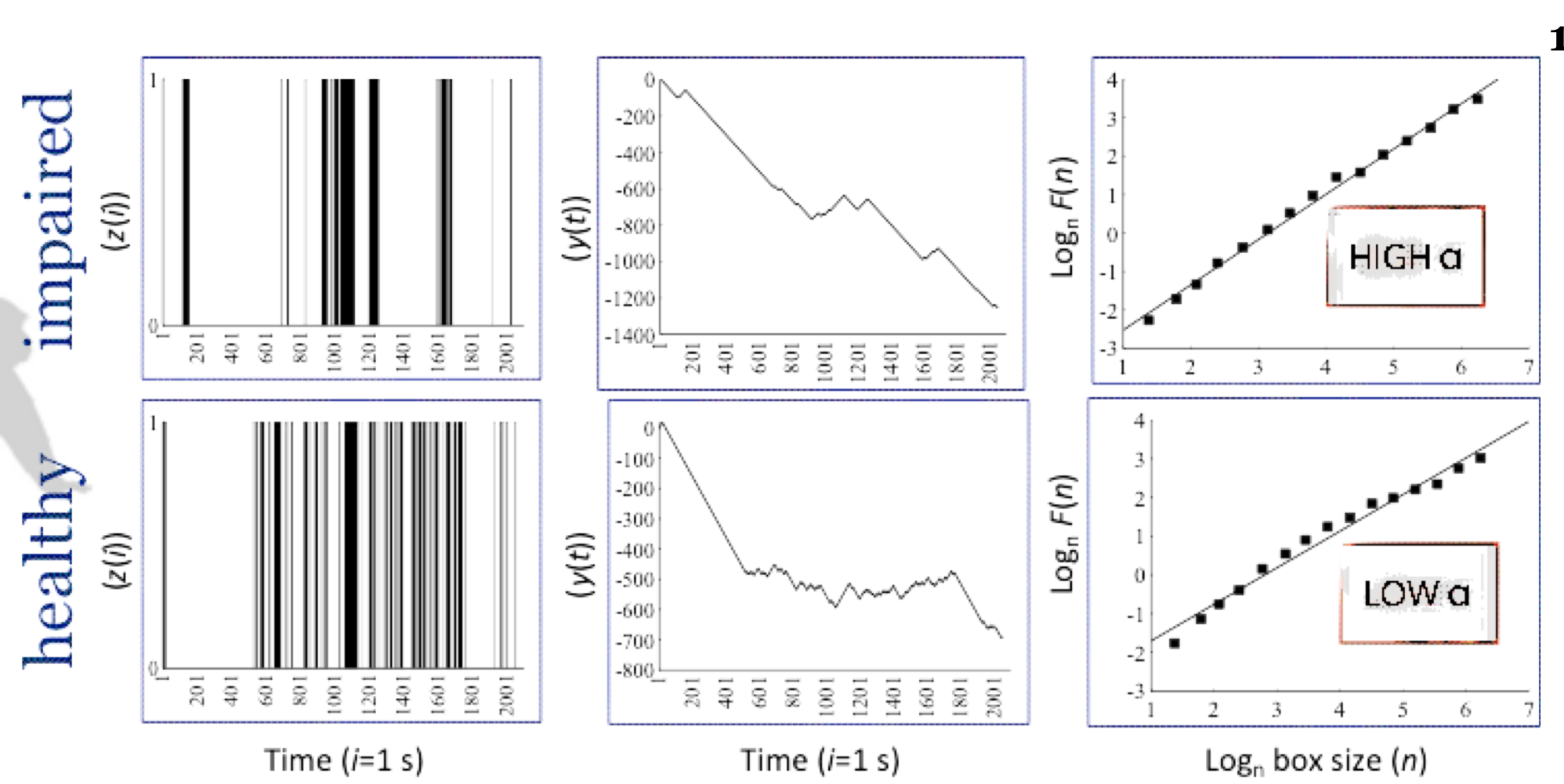
fractal structure is hypothesized to afford behavior

- (i) **better efficiency** (search optimization)
- (ii) **error tolerance** (flexibility)

fractal (n.): a curve or geometrical figure, each part of which has the same statistical character as the whole.

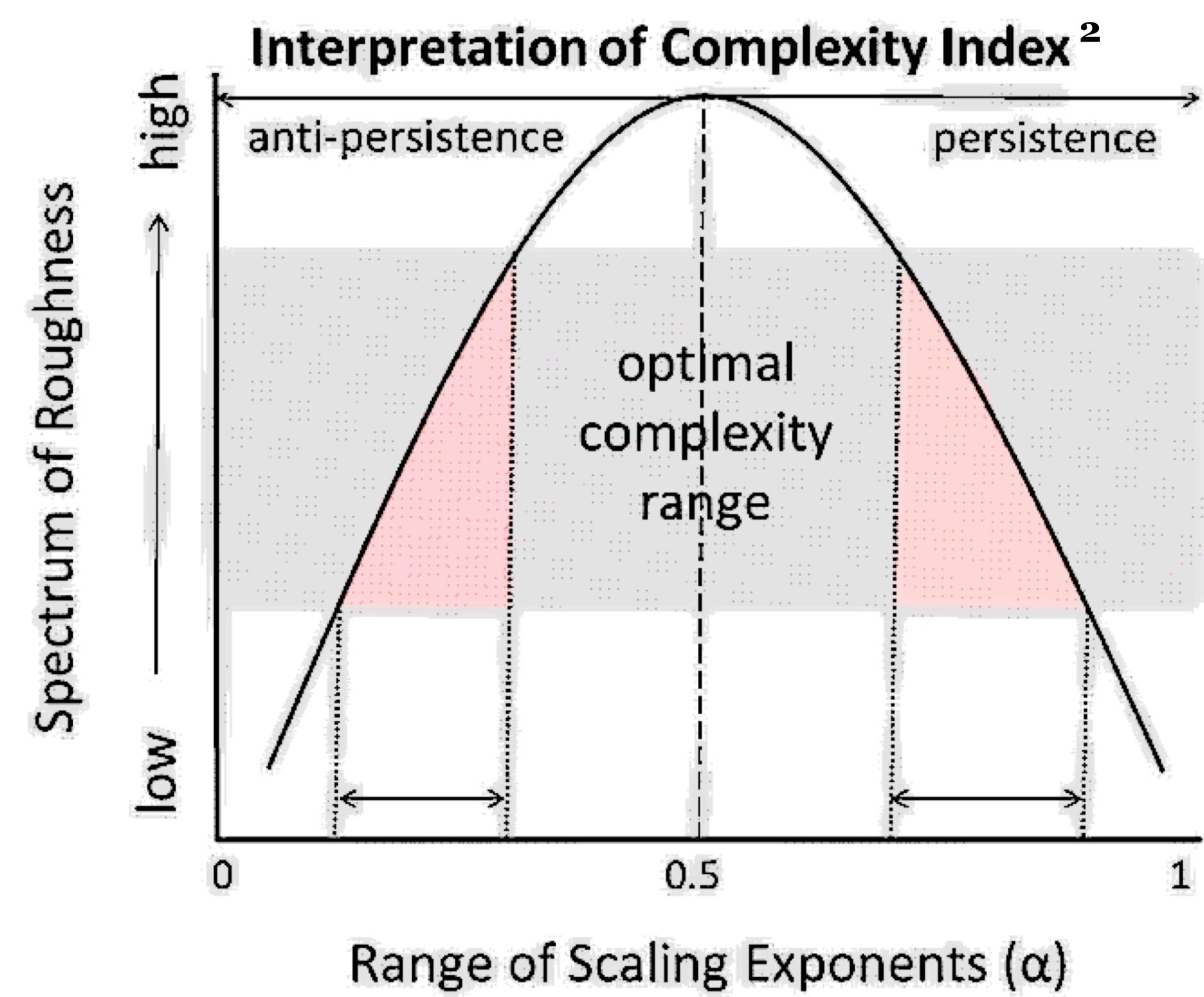
the method

- (i) behavior measured (e.g. activity, movement) as **time series**; (ii) 'random walks' created; (iii) fluctuations plotted across measurement scales; (iv) slope (**scaling exponent**) calculated

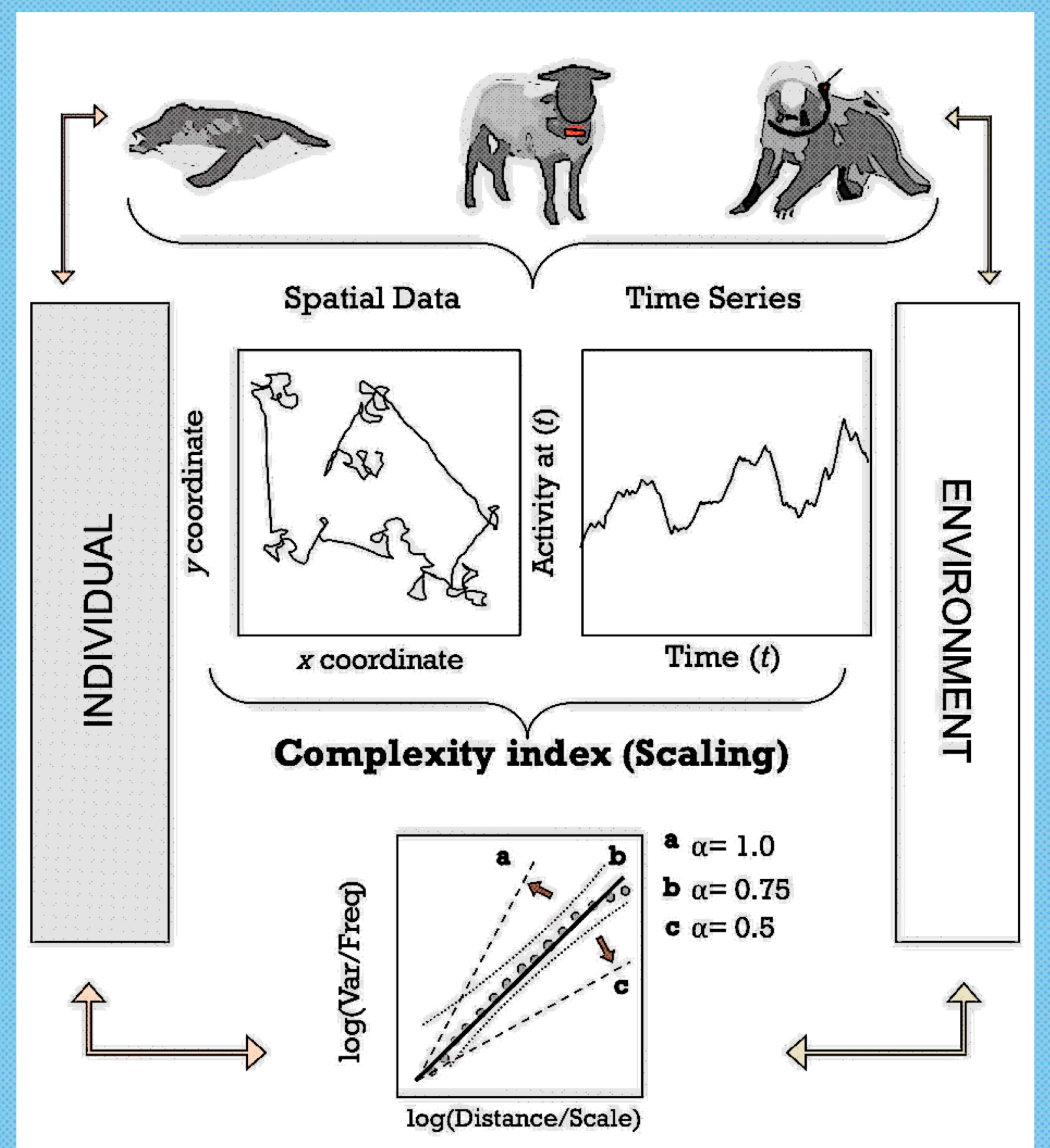


the interpretation

scaling exponents can be thought of as '**complexity signatures**' - variation along a stochastic-deterministic gradient - and compared across animals and conditions



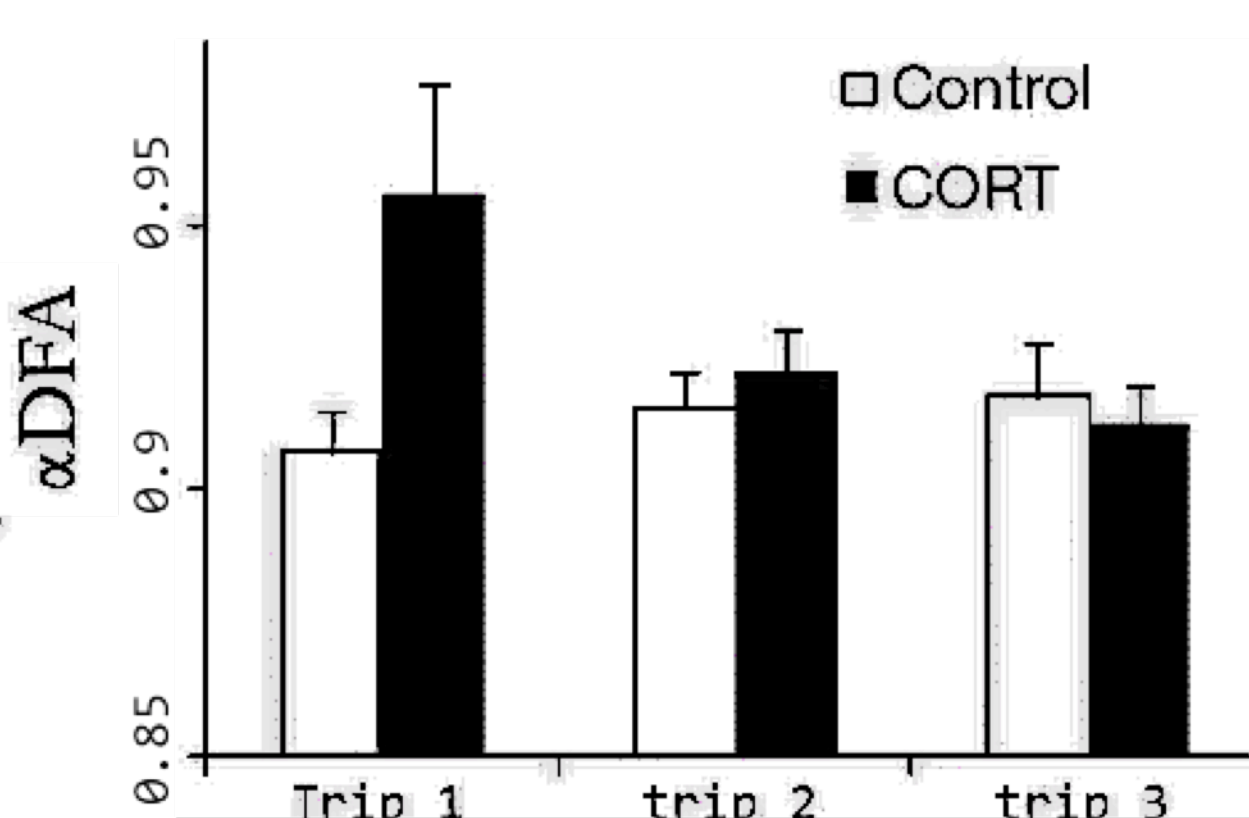
Animals behave in **fractal time**. But the fractal properties of behavior change when the animal is stressed or challenged. Such '**complexity loss**' may provide an **early warning system** of stress in **indicator species** systems.



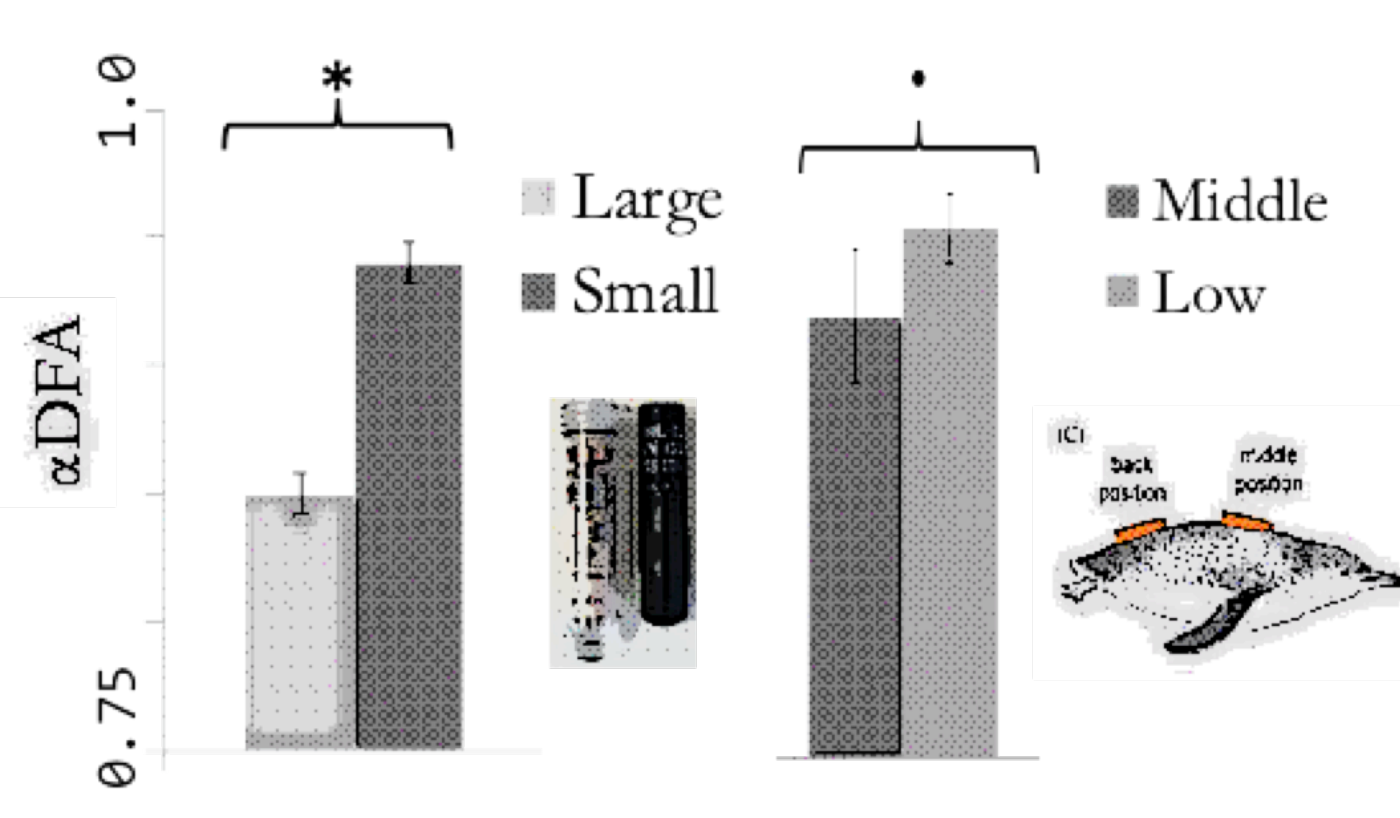
the evidence

multiple studies demonstrate '**complexity loss**' with ecological challenge ...

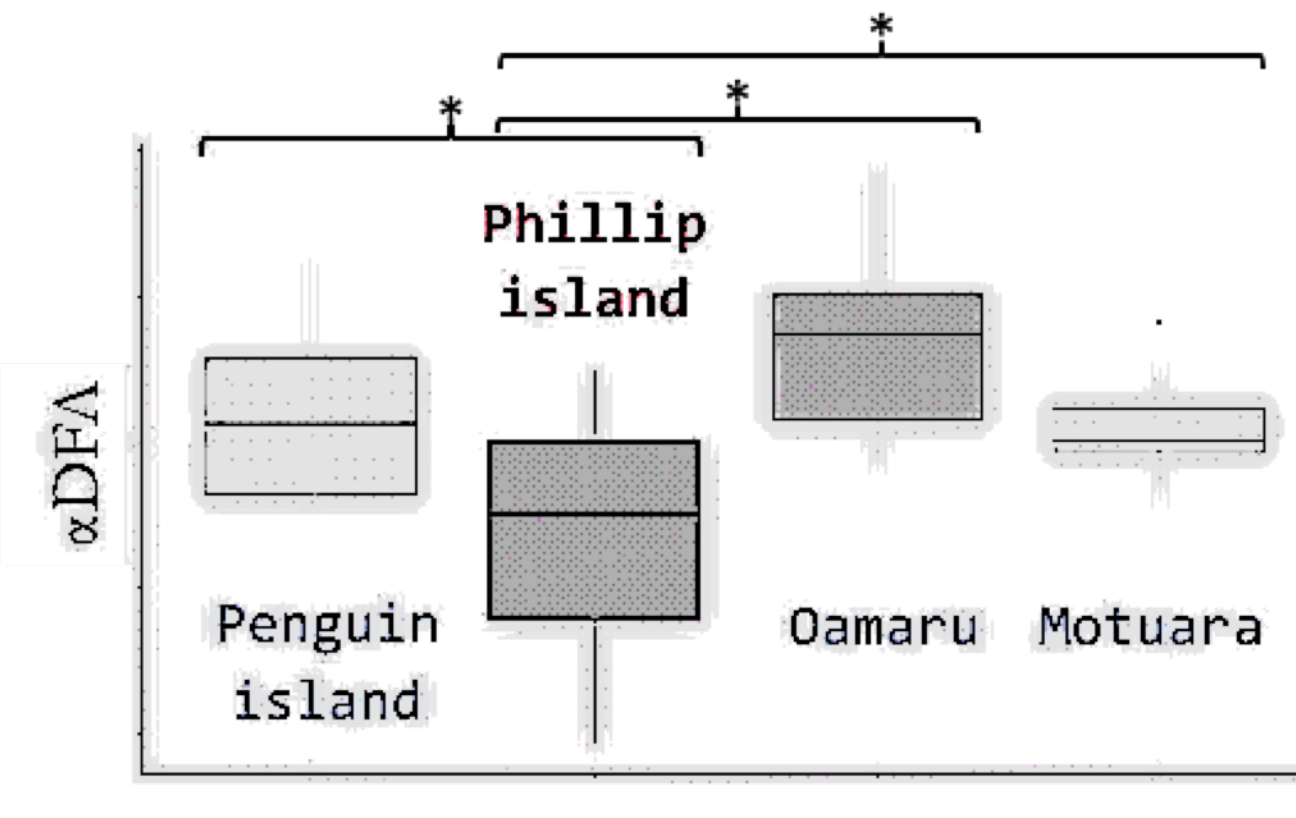
corticosterone implants³



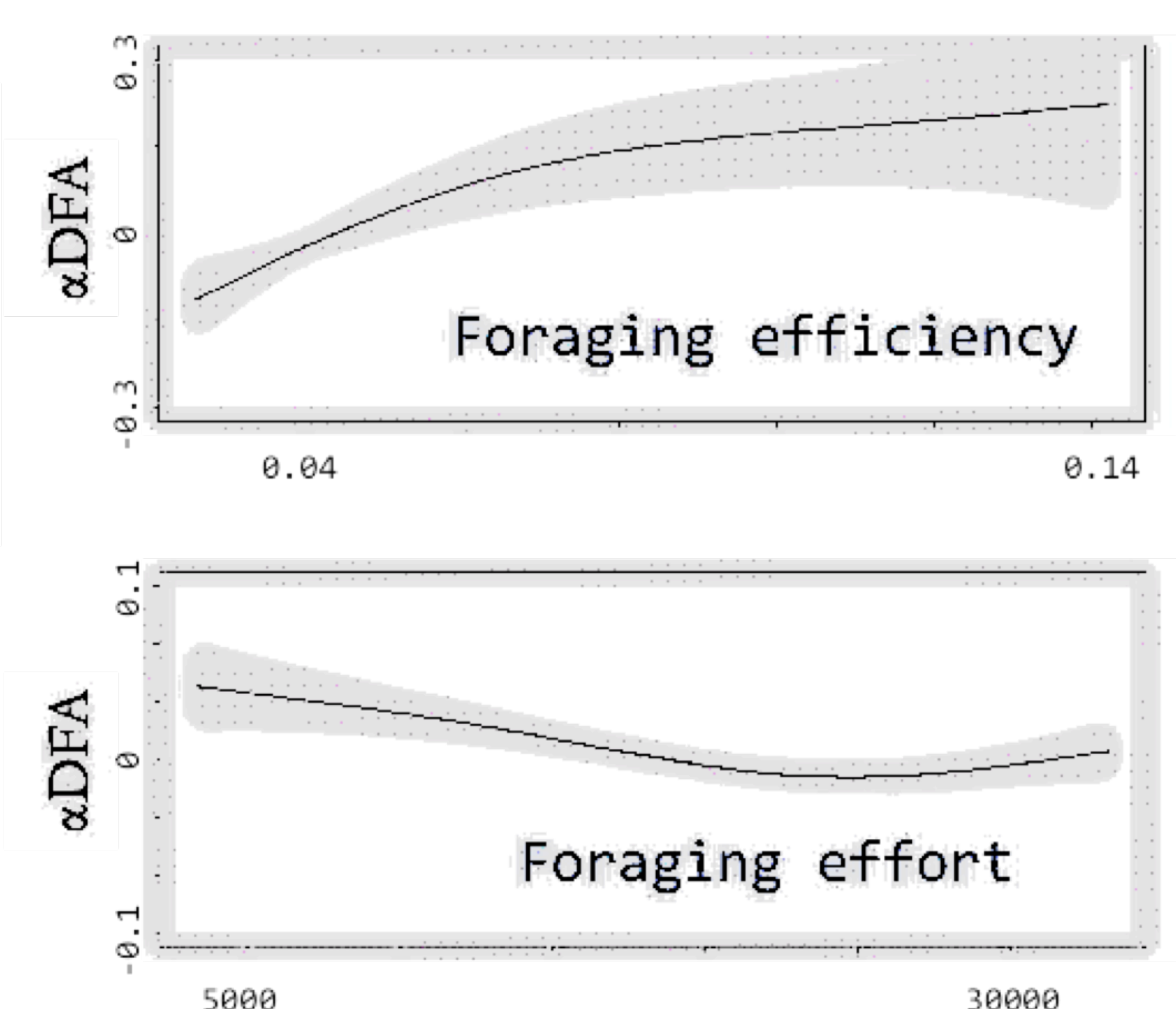
Logger attachment⁴



Colony / bathymetry⁵



Complexity & foraging⁵



the acknowledgements & literature

Thank you Concepcion Alados, Manuelle Cottin, Laure Pelletier, IPEV, TAAF, French National Research Agency, Phillip Island Nature Parks, MEXT, JSPS, WWF, Région Alsace | **Literature** 1. MacIntosh et al 2011, *J R Soc Interface*; 2. MacIntosh 2014, *Primate Res*; 3. Cottin et al 2014, *MEPS*; 4. Meyer et al 2015, *Animal Bioteck*; 5. Meyer et al 2017, *Mar Bio*; see also: Viswanathan et al 2011, *The Physics of Foraging*, CUP; Sims et al 2008, *Nature*; West & Goldberger 1987, *Am Sci*