Oikos

o19998

Gautestad, A. O. 2013. Animal space use: distinguishing a two-level superposition of scale-specific walks from scale-free Lévy walk. – Oikos 122: 612–620.

Appendix A1

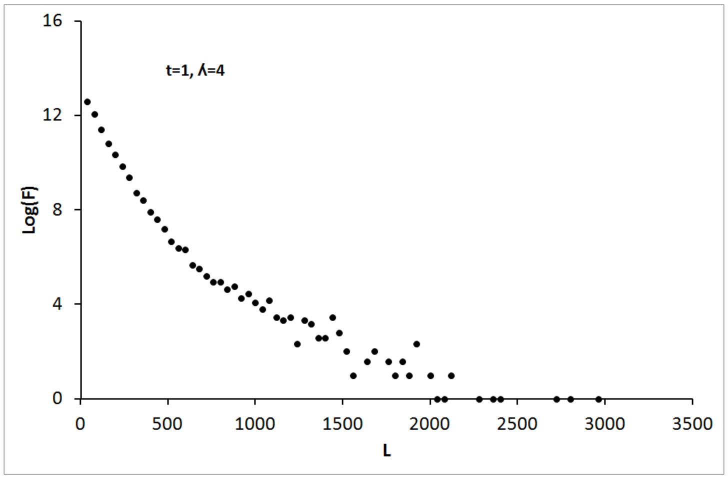
Scale-free and scale-specific step length distributions

In the case of animals that are utilizing their environment in a manner that can be described as Lévy walk, the tail part of a histogram of a set of step lengths (L) versus frequency (F) of steps falling in respective bin classes representing L will tend to follow a power law distribution, $F(L) \propto L^{-\beta}$ with $1 < \beta < 3$, over a spatial scale range from a minimum (L_{min}) to a maximum (L_{max}). Hence, this kind of movement describes a mixture of many small steps (at 'fine' spatio-temporal scales) and gradually fewer long steps towards coarser-grained steps, over a scale continuum. However, any animal has a physical limit for length of displacement during a given observation interval t_{obs}. Thus, at coarser length scales than L_{max} the distribution becomes more like a negative exponential (characterized by a rapidly declining frequency of even larger steps), due to general constraints on movement speed. Step length constraint may also arise due to for example environmental interrupts on long steps in progress (Raposo et al. 2009). Under these constraining instances the distribution can be described by a truncated power law function, where the extreme part of the step length tail falls off more steeply than unconstrained Lévy walk. In spite of truncation beyond L_{max}, the long-step tail part (the part of the distribution beyond median step length) will for a scale-free Lévy walk appear 'fat', i.e. it will show a super-abundance of very long steps relative to the negative exponential step length distribution expected from scale-specific Brownian motion.

As a first approach towards looking for Lévy walk compliance it is common to present step length plots as a log(L) versus log(F) transformation (Sims et al. 2008). A linear slope over a range of log(L) should appear if the movement is Lévy walk-like, since $\text{Log}(F) = -\beta \times \log(L)$. Alternatively, a linear slope in a semi-log transformation (logging y-axis only) would comply with a Brownian motion due to the expectancy of a negative exponential function for step lengths, $\text{F}(L) = \partial e^{-\partial L}$ where $1 / \partial$ is the mean step length (Reynolds 2008). Under log transformation this becomes $\ln[\text{F}(L)] = -\partial L + \ln(\partial)$. In a semi-log plot of $\ln[\text{F}(L)]$ versus untransformed L, a negative and linear slope of magnitude $-\partial$ is expected. Thus, a larger ∂ (smaller mean step length, $1 / \partial$) is equivalent to a steeper slope and larger intercept $\ln(\partial)$ with the y-axis. In other words, a higher frequency of short-range steps on expense of long ones is reflected in a larger ∂. In contrast, the power law function which defines Lévy walk does not contain the scale-specificity defined by ∂.

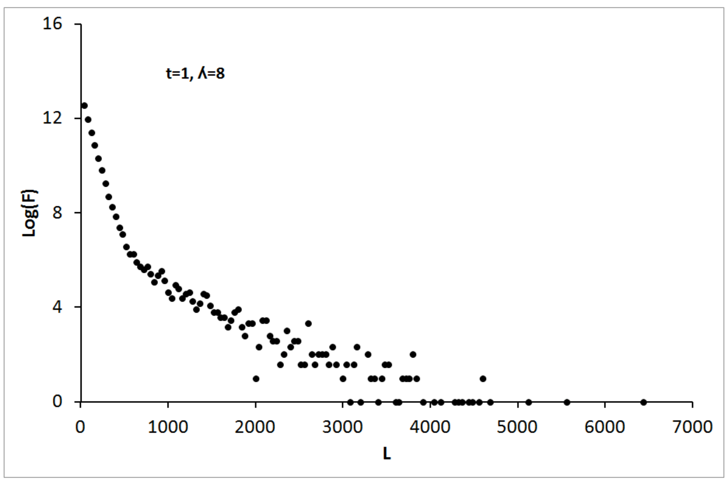
Supplementary results from simulations

Figure A1 and A2 shows increased tendency for a 'broken stick' pattern in a semi-log plot of a binned step length distribution F(L) as the scaling parameter ratio $\lambda = \lambda_2 / \lambda_1$ is increased from 4 to 8. Trivially, the broken stick disappears and the distribution becomes semi-log linear over the entire range for $\lambda = 1$ (not shown), since there will then be no difference in characteristic scale between the two movement components in the superposition.



16
12
8
4
0
Log(F)
t=1, ʎ=4
0
500
1000
1500
2000
2500
3000
3500
L

Fig. A1



16
12
8
4
0
Log(F)
t=1, ʎ=8
0
1000
2000
3000
4000
5000
6000
7000
L

Fig. A2