**Text S2: Diffusive movement in one dimension**

Suppose first that animals perform random walks in $\Omega = \mathbb{R}$ (i.e., one dimension) and let $P_m(x, t)$ be the probability density of an animal being at location $x \in \Omega$ at time $t \geq 0$. The initial value problem that determines the evolution of $P_m$ is given by a diffusion equation

$$\frac{\partial P_m}{\partial t} = D \frac{\partial^2 P_m}{\partial x^2}, \quad P_m(x, 0) = \delta(x)$$

and its solution is

$$P_m(x, t) = \frac{1}{\sqrt{4\pi Dt}} \exp \left( -\frac{x^2}{4Dt} \right), \quad x \in \Omega \text{ and } t > 0$$

(1)

The graph of this function is a Gaussian curve that expands because of diffusion.

**Mean of $P_s$:** It follows from Eq (4) of Text S1 and the fact that $P_m$ is an even function of $x$ that

$$\mu_s = \int_0^\infty \mu_m(t)P_r(t) \, dt = \int_0^\infty \left( \int_{-\infty}^\infty xP_m \, dx \right)P_r(t) \, dt = \int_0^\infty 0 \cdot P_r(t) \, dt = 0$$

(2)

**Scale of $P_s$:** Substituting Eqs (1), (2), and (1*) into Eq (1) of Text S1 yields

$$\sigma_s^2 = \int_{-\infty}^\infty (x - \mu)^2 P_s \, dx = \int_0^\infty \left( \int_{-\infty}^\infty x^2P_m \, dx \right)P_r(t) \, dt = \int_0^\infty (2Dt)P_r(t) \, dt = 2D\mu_r$$

(3)

**Shape of $P_s$:** Upon substituting Eqs (1), (2), (3) and Eq (1*) into Eq (1) of Text S1 we obtain

$$\kappa_s = \frac{1}{\sigma_s^4} \int_{-\infty}^\infty (x - \mu_s)^4 P_s \, ds - 3 = \frac{1}{\sigma_s^4} \int_0^\infty \left( \int_{-\infty}^\infty x^4P_m \, dx \right)P_r(t) \, dt - 3$$

(4)

$$= \frac{1}{\sigma_s^4} \int_0^\infty (12D^2t^2)P_r(t) \, dt - 3 = \frac{12D^2}{(2D\mu_r)^2}(\mu_r^2 + \sigma_r^2) - 3$$

(5)

$$= \frac{3\sigma_r^2}{\mu_r^2}$$

(6)

Note that in our derivation of expressions for the summary statistics (i.e., mean, scale and kurtosis above), we did not assume any specific distribution for retention time ($P_r$).

Furthermore, a counterintuitive feature of our results is that the kurtosis (a key measure of LDD) does not depend on the spatial spreading rate of the animal species (i.e., the diffusion constant $D$).