Spatio-temporal dynamics of bat population in point-patch habitats

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Introduction

We are interested in analyzing how the spatial distribution, dispersal rates, and carrying capacities of caves affect equilibrium (long-term steady-state) populations of Mexican free-tailed bat (*Tadarida 44 brasiliensis mexicana*(Tbm) demographics throughout their year long life cycle. We derive equations which track the demographics of the bats during dispersal stage around the caves.

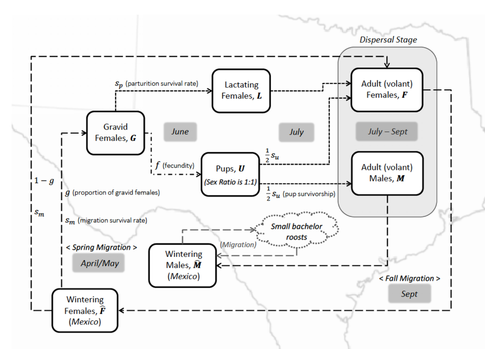

Figure 1:Mexican free tailed bats lifecycle.

A model of a population in point patch habitat(maternity caves in Texas) in which bats use olfactory gradients to find new patches(caves) upon dispersing.

Integro Difference Model

Logistic growth model for the daily population of bats in the maternity cave throughout the dispersal stage for $N = 1, 2, ...i$ days where rate and carrying capacity is climate dependent.

$$P_i(n+1) = P_i(n) + r_i \cdot P_i(n)\left(1 - \frac{P_i(n)}{C_i}\right) \tag{1}$$

- Assume that the birth rate and carrying capacity of a cave (and immediately surrounding area) increases with local annual mean temperature as well as with annual rainfall

On a 1-dimensional landscape, we assume that bats fly out of caves at dusk and disperse according to a probability distribution $K_i(x)$, called the **dispersal kernel**,with parameters that depend on local environmental and climate conditions near each cave. We use **Laplace Distribution** as Dispersion Kernel

$$K_i(x) = \frac{1}{2d_i} \cdot e^{\frac{-|x|}{d_i}} \tag{2}$$

To obtain the total density of bats that dispersed from all caves, denoted by $B(x)$, we add the densities from all caves,

$$B(x) = P_1(n)K_1(x - x_1) + P_2(n)K_2(x - x_2).... + P_N(n)K_N(x - x_N) : \tag{3}$$

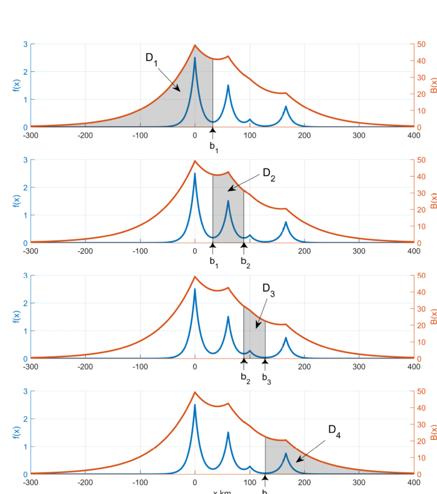

Figure 2:Minimums of f are denoted by b_i, each of which forms the boundary between the region in which olfactory cue concentration gradients lead bats to cave i and the region in which they lead bats to cave $i+1$. The total number of bats attracted to cave i on day n, denoted by $Di(n)$, is the area under the bat density curve $B(x)$

Extension to 2-Dimensional landscape

Consider a set of N caves located at points $(x_1; y_1), ...(x_N, y_N)$ on the xy-plane. Using a bivariate Laplace distribution as dispersal kernel, $K_i(x, y)$,

$$K_i(x, y) = \frac{1}{2\pi d_i^2} \cdot e^{-\frac{\sqrt{x^2+y^2}}{d_i}} \tag{4}$$

we modify (4) as

$$B(x, y) = P_1(n)K_1(x - x_1, y - y_1).....P_N(n)K_N(x - x_n, y - y_n) \tag{5}$$

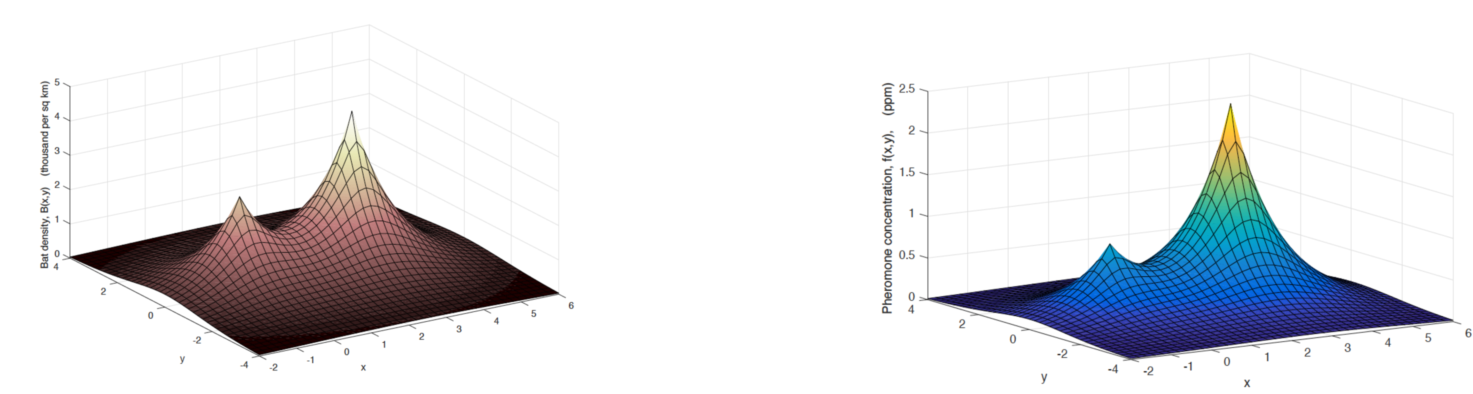

Figure 3:Left: $B(x, y)$ *across* 2*-dimension*, Right: *Odor concentration function* $f(x, y)$ *across* 2*-dimension*

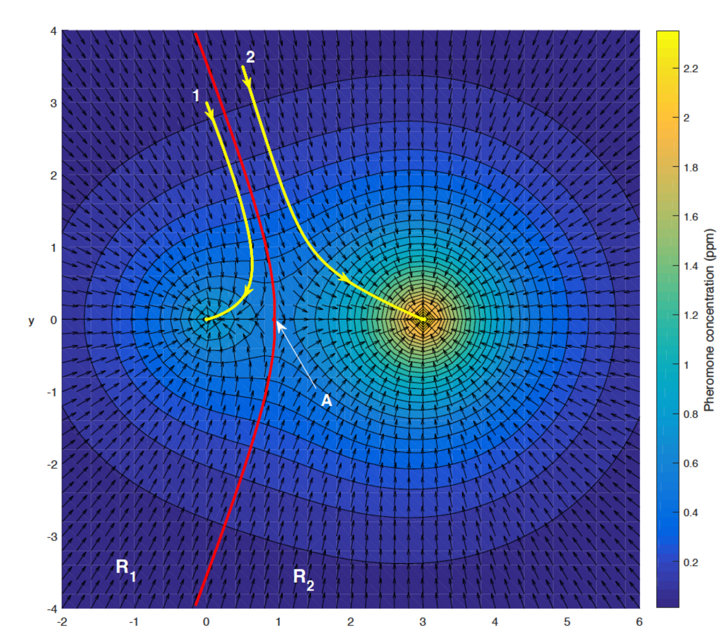

Figure 4:gradient vector of $f(x; y)$ field (arrows) for caves with two example bat trajectories (yellow curves) in cave finding after foraging. The boundary separating the region, R_1, in which bats return to cave 1 from the region, R_2, in which bats return to cave 2 is called a separatrix (red curve)

With an arbitrary number of caves (N), the gradient field will partition the plane into N regions, $R_1, R_2, ..., R_N$, in which bats return to caves $1, 2, ..., N$ respectively. The total number of bats attracted to cave i after foraging on day n is determined by the total density of bats in region R_i,

$$D_i(n) = \int\int_{R_i} B(x, y)\, dA \tag{6}$$

Model Parameterization, Simulation, and Prediction

4-Cave Model Simulation

We also investigate the effect of climate conditions on equilibrium populations.We provide a brief expository analysis of the 4-Cave model in 1-dimension here.

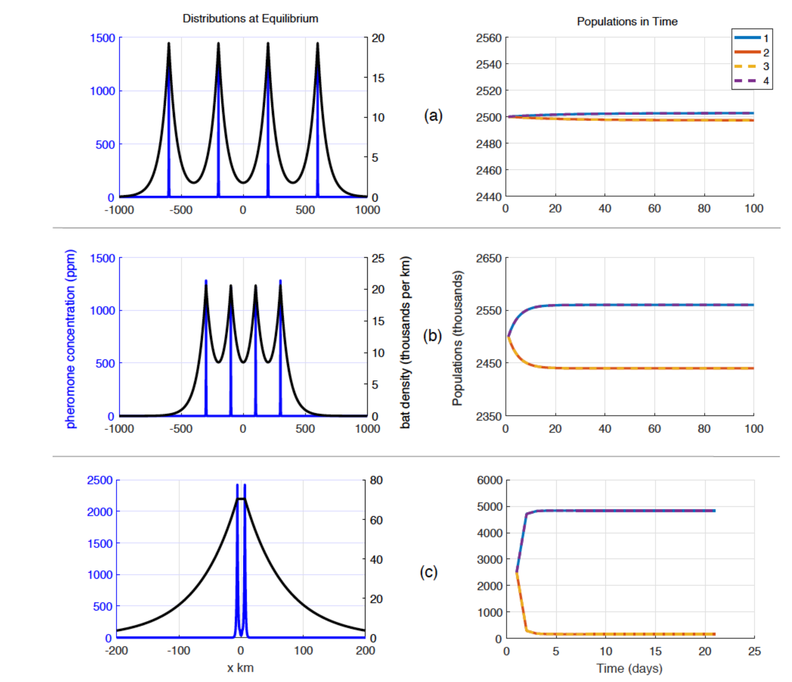

Figure 5:Simulation of the model with constant dispersal rate (65km) and no demographics ($r_i = 0$ for 4 equally spaced caves using the Laplace distribution

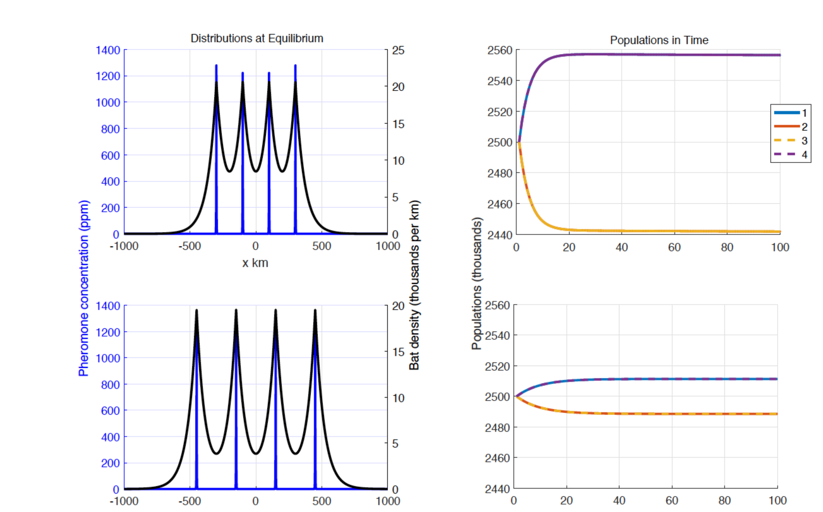

Figure 6:Simulation of the full model with constant dispersal rate (65 km) and carrying capacity (2.5 million) for closely situated caves (a), and caves significantly far apart (b). Dispersal is more of a factor than carrying capacity in determining equilibrium populations when caves are close together. If caves are far apart, the system tends more toward the carrying capacities than the intrinsic dispersal-driven equilibrium populations.

Equilibrium Analysis

Simulations give good qualitative insight into the spatio-temporal dynamics of bat populations in point-patch habitats.Our future goal is to use the real data from sensors to derive model for equilibrium populations in terms of spatial distribution of caves, as well as climate-dependant dispersal rates, birth rates, and carrying capacities. We can then use such models to analyze the effect of local climate conditions on long-term (equilibrium) populations.

Acknowledgements

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