Relative Encounter Rates
a scale-invariant home-range based measure of animal encounters

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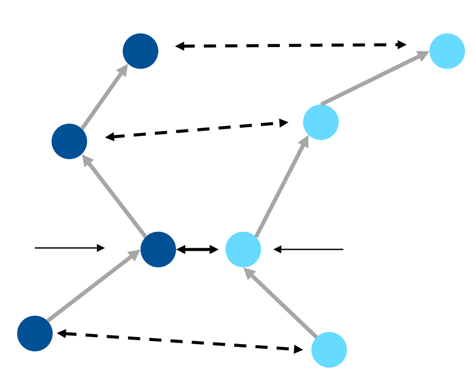
Introduction

Natural animal encounters are fundamental to ecology, and quantifying encounter rates allows for better inference of animal mating systems, population density, and human-wildlife conflicts.

Two current metrics of encounters:

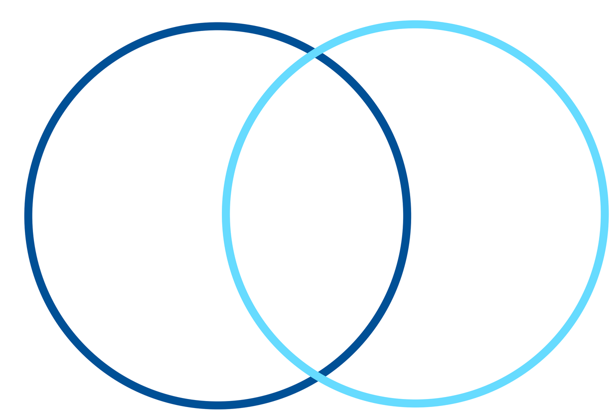
Trajectory based



Encounters are pairs of points within an arbitrary distance.

E.g. **PROX**, CA, Don, Cs

Home range based



Home range Overlap ↑ Animal Encounters ↑

E.g. **Bhattacharyya coefficient (BC)**, UDOI

	Direct measure of variable of interest	Independent of Sampling frequencies & # of points	Can control for auto-correlation	Represents animal long-term behavior	Does not require simultaneous sampling	CI and error measures can be estimated
Trajectory based	✓	✗	✗	✗	✗	✗
Home range based (add RER)	✗	✓	✓	✓	✓	✓

Our new metric, *Relative Encounter Rates*, has long-term properties of home range metrics while being measured in number of encounters/average number of encounters with previous tracks

$$RER_{ij} = \frac{\mathcal{E}_{ij}}{\sum_k \mathcal{E}_{kk}};\ \mathcal{E}_{ij} = \frac{\gamma\left(\sigma_i^2+\sigma_j^2\right)}{8\pi\sigma_i^2\sigma_j^2} BC_{ij}^2$$

$\mathcal{E}_{ij}$ - encounter rate between two animals (Encounters/time, Martinez-Garcia et al.2020)
$\mathcal{E}_{kk}$ - encounter rate between an animal and its past tracks (Encounters/time)
σ_i^2 - Home range variance for animal i (assuming animal has a Ornstein-Uhlenbeck movement)
BC_{ij} - Bhattacharyya coefficient between the two range distributions
γ – Encounter Speed (1/time). Impedes calculation of encounter rate proper, but cancels out in RER.

Methods

We show that RER combines the best of both worlds with four study cases:

Simulation study. We placed two individuals exibiting to Ornstein-Uhlenbeck movement progressively closer to one another. This scenario was repeated with 100% to 10% of data. PROX should change with data coarsening level, while BC and RER should not.

Jaguar Polygyny. We tested if Chaco/Pantanal Jaguars (*Panthera onca*) meet opposite-sex individuals more than same-sex individuals. PERMANOVA based on encounter rates was used for testing, along with visual inspection for clustering in encounter rates networks. Data from Morato et al. (2018).

Dearest enemy in bears. We tested whether a pair of female brown bears (*Ursus arctos*) would decrease their encounters per season over the years. Bears sampled for 13 seasons. Tested using custom-made F-test for RER and BC, and LM for PROX. Data from Belant & Follman (2002).

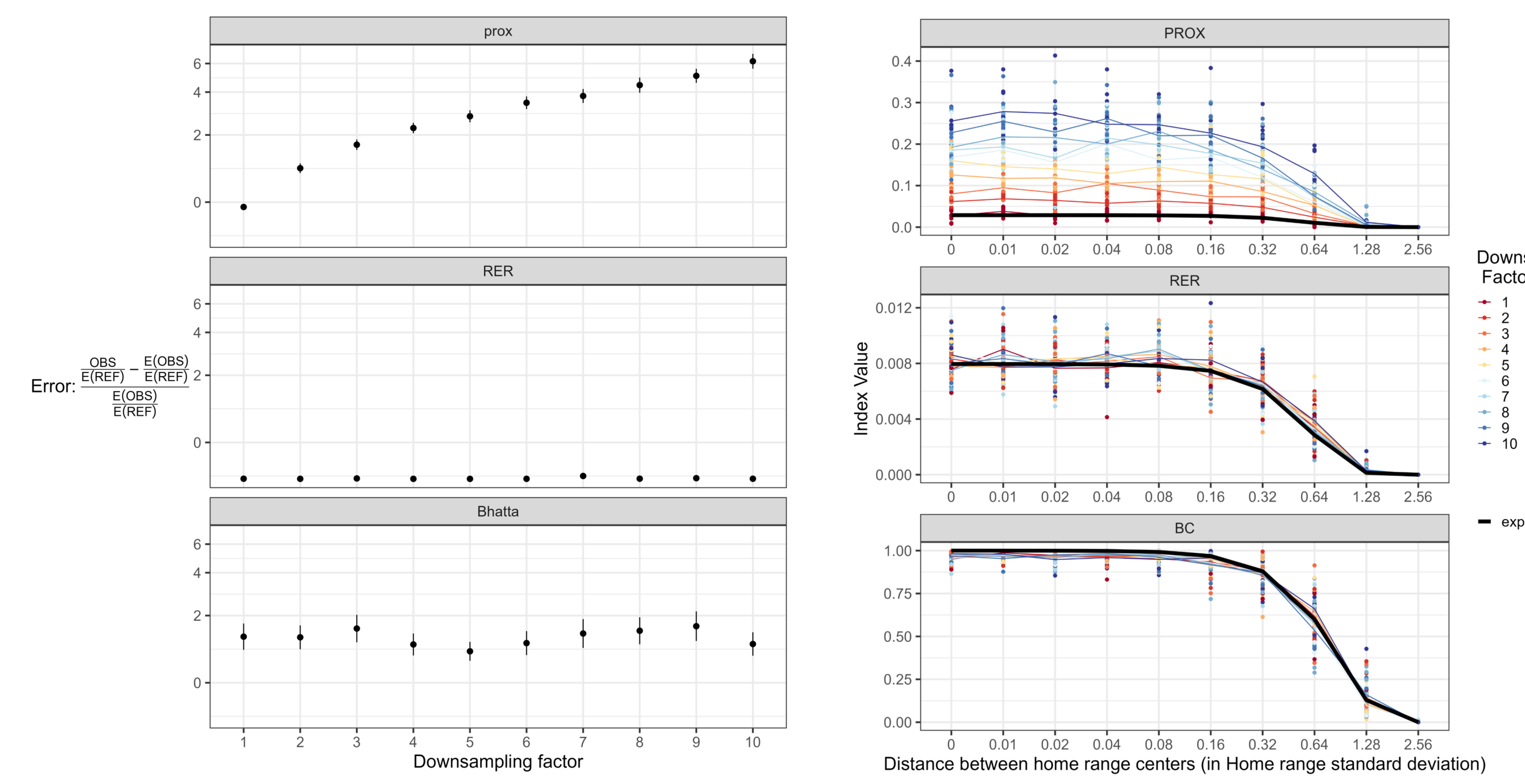
Agriculture vs Tapirs. We tested if tapirs *(Tapirus terrestris)* in the cerrado (cultivated) meet less frequently than tapirs in the Pantanal (conserved). Test based on encounters rates conducted with a LMM/Mann-Whitney. Data from Medici et al. (2022)

Results

Our metric is already implemented in the `R` language, on package `ctmm`, function `rates()`. See R documentation in: bit.ly/useRER

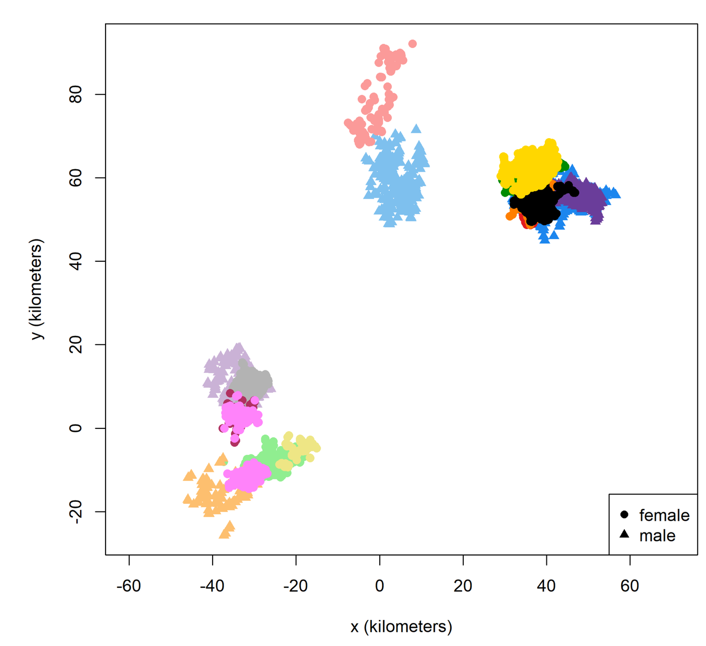
Simulation:

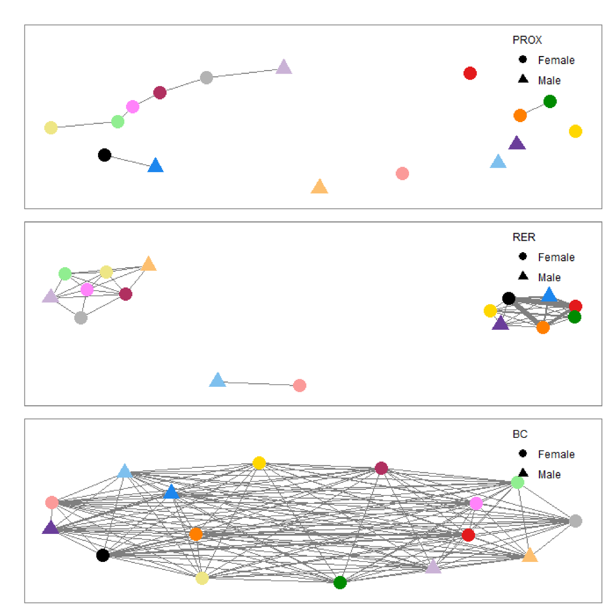
PROX overestimates encounters in coarsely sampled data. RER and BC do not.
PROX also overestimates encounters when home ranges are closer to one another.
This error is worse in coarsely sample trajectories.



Jaguar Polygyny:

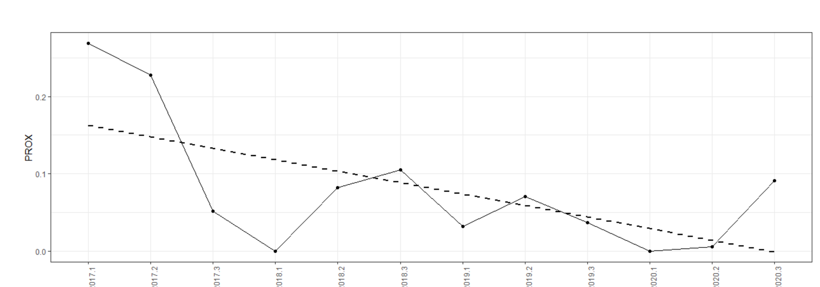
All metrics rejected polygyny
(PROX: $F_{1,14}$=-1.2319 p=0.530; BC: $F_{1,14}$=-1.0249 p=0.777, RER: $F_{1,14}$=-2.5334 p=0.732).
However, RER could represent spatial clusters while PROX and BC could not. PROX does not perceive most interactions. BC has no clear cutoff for "no interaction".

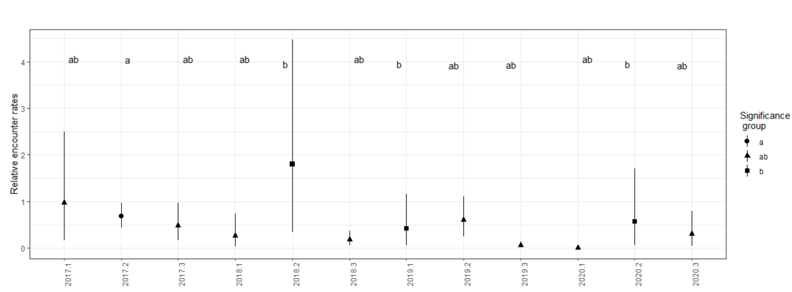


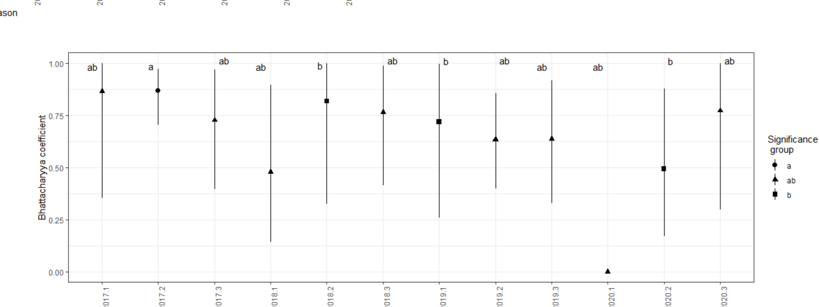


Dearest enemy in bears

Neither RER or BC corroborate a decrease in encounters with passing seasons. PROX did, likely due to an overestimation.







Agriculture vs Tapirs:

All three Mann-Whitney tests detected differences.
(PROX:U = 17059, p = 0.0123; RER: U = 9146, p < 0.0001; BC:U=6705 p<0.0001)
A more appropriate LMM failed to reject the hypothesis in BC and RER.
(RER: β = 0.0561 ± 0.0335, t = 1.674, df = 46.3046, p = 0.1008, BC: β = -0.0261 ± 0.0137, t = -1.899, p = 0.0868)
LMM could not be done with PROX due too many zeros that caused model matrix singularity.

Conclusions

1. PROX systematically committed type I errors, overestimating encounters in our simulations, and supporting interactions absent in other metrics.
2. BC does not allow for identification of spatial clusters for lack of a natural "no interaction" cutoff point.
3. RER suffers neither of these two problems, so we advocate its use as a general encounter rate estimator and as a basis for hypothesis testing.

References
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