Essay on *Wildlife population inference from limited data* by David Borchers

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Abstract - *Model-based inference is a powerful tool when dealing with limited and sparse data as the information on wildlife populations. By using sensible statistical models, it accurately predicts real-world data, like animal abundance, distribution, and activity over time.*

Humanity possesses very little information on other species compared to their own. Understanding abundance and distribution patterns of wildlife populations are imperative to their conservation effort for example so how can we infer the dynamics of these populations by the relatively low sampling data that we have?

We could simply survey the density of species over several specific areas, yielding a density map. However, this is of little use since we could not understand the mechanisms behind that density, what drives the species to be there. The same happens for activity patterns or animal movement, so other approach should be considered. In this talk, Model-based inference is the subject.

With model-based inference, mathematical models can be used to make inferences about complex dynamical systems when they are quantitatively fitted to data. This approach allows us to formally and quantitatively test and compare competing hypotheses, and allows us to make quantitative predictions for empirical testing. It is a powerful and rapid way of culling wrong hypotheses.

To choose our mathematical models, it is essential to understand the underlying processes in a given situation. David separates this *underlying process* into two parts: the *ecological process* and *observation process*. The ecological process is for example saying that the distribution of animals in space is uniform and the observation process says that the probability that one individual is detected is equal to all members of the population.

One case study was that of bear hair traps and how bear density is affected by some case features as road density, habitat suitability, and presence of natural parks. Each of these features is an explanatory variable so each is multiplied by a parameter in our ecological process model, i.e. bear density, so we can understand the weight of each parameter by fitting with the bear hair trap data. This yielded that road density affected negatively bear density, and being in a park did not affect density at all. So from a simple model, we could infer bear behavior. [1]

Now we can create an observational process. Considering that the animal spends a decreasing amount of time the farthest from its activity center it is, we create a model of how the animal moves around its activity center. In this case, the model was dependent on two parameters: the *activity* that is related to how much time the animal spends at the activity center and *range* related to how far away from the center the animal ranges. By again best fitting with observational data we can infer animal movement and its actual activity centers.

So from a relatively small amount of data, we estimated the density of bears in space, animal activity and range, due to our search in understanding the underlying mechanisms that drive the behavior of the animal. This was however a simple case where the animal ranged homogeneously around their activity center. This is not common in animals since they are embedded in an obstacle-filled complex environment. Like a tiger in a river habitat. The tiger *can* swim however it'll not spend the energy if it needn't. We can consider this in our models by adding a *resistance* parameter, therefore the animal will choose the least effort path.

Since this resistance is a parameter after all, by fitting the model with the data from Sundarban tigers, we could infer how their ranges depend on their habitat and, perhaps in a more profound way, their habitat preferences. Tigers would not generally cross bodies of water, staying inland. David notes too the differences between males and females, females having a lower range parameter so never drifting much from their activity center.

By combining the least effort distance maps around an individual activity center with its daily activity patterns, we can make a model that says how this individual moves throughout the day, i.e. the probability of it being at a given place at a given time of day. David continues to explore this concept by scaling this time of model to years timescales. For this, other parameters need to be taken into consideration like birth and death parameters, to infer population dynamics, but some are not so obvious too, like the shift of activity centers through time.

So in just a few examples and a small dataset of point-based information, composed of randomly placed traps (cameras, hair), we've estimated the abundance and how the density of bears changes with the environment, the distribution and habitat preferences of tigers, activity patterns over different timescales and consequently abundance dynamics. David notes that the unexpectedness of some parameters, like the drift of activity centers, leads to the awareness of new ecological processes, showing that the understanding of the underlying mechanism of model-based inference has a fundamental aspect in the way that we do science.

REFERENCES

[1] Efford, M. G., Borchers, D. L., Mowat, G. (2013). Varying effort in capture–recapture studies. Methods in Ecology and Evolution, 4(7), 629-636. https://doi.org/10.1111/2041-210X.12049