Literature to emulate

* Grimm et al 2020
  + A good review of the ODD protocol
  + “Overview, Design concepts, and Details”
* EDA-based ABM simulations (Butts et al 2022)
  + Deer example of EDA in ABM
  + Uses ODD
* abmAnimalMovement (Marshall and Duthie 2022)
  + “External influences are implemented via matrices describing landscape characteristics (e.g., shelter quality, foraging resources, movement ease), and predefined points describing shelter sites and points the animal aims to avoid.”
  + Incorporates behavioral states (foraging, resting, exploring)
  + Allows for diel cycles, with transition matrices changing over time
  + “In addition to the predefined attraction to shelter sites, the abmAnimalMovement package allows for a more dynamic attraction to areas of high resource quality.”
  + Separates movement scales: “destination” versus “local” preferences; this means that while they could head towards an area of high appeal, they may travel through low-quality areas to get there
* SiMRiv (Quaglietta and Porto 2019, Quaglietta et al 2019)
  + “We are aware of no tools allowing simulating spatially-explicit multistate Markovian movements constrained to linear features or conditioned by landscape heterogeneity, which hinders movement ecology research in linear/dendritic (e.g. river networks) and heterogeneous landscapes.”
  + “allowing continuous-space mechanistic spatially-explicit simulation of multistate Markovian individual movements incorporating landscape bias on local behavior.”
  + “it avoids unrealistic assumptions, such as animal omniscience and planned final destination, generally found in the least cost path (LCP) modelling approach”
  + Con: doesn’t seem to have any features that would attract animals (e.g. artificial waterholes); how would I change the resistance layer over time?

Other packages/software

* HexSim (Schumaker and Brookes 2018)
  + Seems to be more about long-term range shifts and population dynamics
  + GUI so I don’t know how much I’ll be able to edit
  + Transforms linear features into hex boundaries and this is a key feature of our system, seems like an afterthought here?
* abmR Gochanour et al 2023)

Steps

1. **Define metrics**: Define and link specific quantitative metrics (see Butts et al 2020 paper) to the qualitative patterns we think are necessary to replicate (table below), using EDA to explicitly define these characteristics. Here we might also define different movement or activity states.
2. **Gather spatial data**: List spatial features and gather spatial data. Perhaps combine a few to have one map of water, one of landscape viability, and one of linear features. Would Robin’s Circuitscape output be useful here?
3. **Gather agent attributes**: List movement characteristics of agents and gather parameters from literature or from the data.
4. **Model implementation**: Choose a model or two and get a basic version running
5. **Model selection**: Try out simulations with different combinations of agent attributes and spatial features, then calculate metrics from step 1 to compare between models. Which ones accurately replicate the critical spatial patterns?
6. **Add time**: Once we have an MVP for the spatial component, what about temporal (seasonal) changes in the space? Specifically, vegetation, temperature, and water supply.
7. **Add individualization**: Elephants are not just randomly wandering about the landscape; they’d likely remember waterholes and fence gaps. In addition, bulls are known to *create* fence gaps; agents should be able to modify their landscape. Also, what about activity state? Could draw from TOD, time since last state change, etc. and determine whether the agent is foraging, exploring, or resting. This would then determine the characteristics of the distribution from which we’re drawing step lengths and turning angles (internal state x landscape resistance perhaps). Or is that too much in the weeds?
8. **Additional extensions**: What about adding different species (roan, oryx, X species with Y characteristics?). Steve suggests prioritizing buffalo and cattle since they’re the impetus for putting these fences up in the first place. Robin suggests using buffalo data from the Caprivi strip, Shirley on zebra; zebra and buffalo don’t cross often. What about expanding more beyond N and B into the rest of KAZA. Also implications of future infrastructure plans, e.g. the railway across the Caprivi strip (along the highway) or if they paved certain corridors. Railway in NE Hwange.

**Patterns and Metrics**

See Butts et al 2022 for a more detailed look at this EDA approach for creating an ABM.

|  |  |  |  |
| --- | --- | --- | --- |
| **Pattern** | **Scale** | **Features** | **Metric** |
| Elephant movements trace along fences and channel along omiramba | Spatial | Fences &  omiramba and om |  |
| Pinch points across roads and at rivers | Spatial | Roads and rivers |  |
| Habitual/repeated movement to and from water sources, especially artificial waterholes | Spatial and Temporal | Natural & artificial waterholes |  |
| Deflection/permeability differences by sex and boundary type (fence [and fence type], road, river) | Spatial | Fence, road, river | Encounter and crossing rates should be similar to those found in Naidoo et al 2022 (see table below) |
| Bulls cross fences more often in the wet season (?) and animals move away from water sources in the wet season (expansion contraction) | Temporal | fences |  |
| Elephant attraction to some areas with higher quality resources? | Spatial and Temporal? | Landcover type? |  |

Fences that are rebuilt w/o a cable, they don’t really function as fences; fence structure plays a role

Human settlements, Robin has been using a world settlement footprint product (10m sentinel based)

Shirley mentions that some of the waterholes in Hwange aren’t being filled as much due to budget constraints, and elephants are moving into Botswana earlier in the year to get water

Thumbnail of project and applications

**Feature permeability** (Naidoo et al 2022)

Percentage of crossings @ 1km encounter threshold

(should we use 25km instead? What is the utility of a larger threshold if we are controlling the movements?)

|  |  |  |  |
| --- | --- | --- | --- |
|  | **River** | **Road** | **Fence** |
| **Female** | 10.1 | 15.3 | 0 |
| **Male** | 14.5 | 25.8 | 3.5 |

**Spatial data**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Description** | **Source** | **Res** | **Extent** | **Type** | **Status** |
| Elevation (DEM) and slope (calculated) | USGS SRTM ([link](https://earthexplorer.usgs.gov/)) | 30m | KAZA | Raster | Obtained, reprojected, and mosaicked on ArcGIS; slope calculated in ArcGIS |
| Human settlements | ESA World Settlement Footprint 2019 (Sentinel-1 and -2) ([link](https://geoservice.dlr.de/web/maps/eoc:wsf2019)) | 10m | Africa | Raster | Obtained |
| Landcover | WWF (link? What dataset did these come from?) | 10m | Africa | Raster | Obtained |
| Ephemeral surface water | Schaffer-Smith et al 2022 (Sentinel-2) ([link](https://doi.org/10.4211/hs.6f5b34803dc247e890925d7f26b04a3b)) | 10m | Khaudum | Raster | Obtained for Khaudum |
|  |  |  |  |  |  |
| Fences | Robin... where did he get these? | NA | KAZA | Vector | Obtained |
| Roads | OpenStreetMap (Angela) (see metadata file) | NA | KAZA | Vector | Obtained |
| Rivers | Digitized by Robin from various sources ([link](http://gaia.geosci.unc.edu/rivers/)) (see metadata file) | NA | KAZA | Vector | Obtained |