### ODD

#### ODD Purpose

The purpose of the model is to simulate fine-scale regular movements of oilbirds based on the underlying environment and memory, and investigate how the interactions between environmentally driven movements and the presence of five key food sources influences the sustainability of an oilbird population for 2500km2 grids in Venezuela.

#### ODD State Variables and scales

All individual oilbirds are treated identically, with no low level state variables. Oilbirds have variable energy, which is a combination between energy obtained from the fruit and energy utilized to move. The environment is characterized by three states: land cover, resource availability, and memory. Land cover is a static variable, as it assumed it will not change substantially when the model is run for one year. Land cover is comprised of four covers: evergreen broadleaf forest, cropland, other habitat and distance to rivers. The land cover information was obtained from MODIS (MCD12Q1) land cover product at 1000m resolution (LP DAAC 2013) and the river dataset was obtained from Daly (2015). Resource availability is defined the by annual amount of fruit produced by the oilbirds food sources. Fruit production is therefore the annual amount of fruit produced at a 1km resolution for five widespread tree species which make up the oilbirds diet (Bosque et al. 1995). An estimate of 250 fruits per tree for *Nectandra membranacea, Ocotea floribunda, Persea caerulea* and *Prestoea acuminata,* and of 1250 fruits per tree for *Euterpe precatoria* was made for species. Tree density, which was taken as the maximum abundance recorded in a comprehensive study of the Amazonian tree flora (ter Steege et al. 2013) was then used to extrapolate the total amount of fruit to a 1km resolution. Memory is recorded as a binary variable, meaning if a grid is visited by an individual oilbird, the individual remembers the coordinates of the location.

#### ODD Process Overview and Scheduling

The model is run at 10 minute time steps between the hours of 10pm and 10am for a one-year period. The probability of movement by an individual was developed by using step-selection function (SSF). A number of possible steps are identified by an individual oilbird, and the variables along the steps are analyzed using the model generated from the earlier conditional logistic regression parameters. From this regression model, one final step is chosen based on the likelihood of each of the possible steps available.

#### ODD Design Concepts

*Emergence:* The emergent phenomena from the interactions between the agents and the environment is a measure of how sustainable the environment is for the agents. As such, if the agents do not consume a suitable amount of resources then they die, and if they do consume a suitable amount of resources they do not die. A starting value of energy was equated to an equivalent of 1 weekly estimate of food intake (consumption of 1 biotic resource at each time step = 540) due to the relatively high energy demands of frugivores. The final outcome of this model is a figure representing the number of agents remaining after the model has simulated movement and environmental interactions for a year.

*Adaptation:* The agents adapt their memory of the environment by storing the locations of previously visited locations. The agents are allowed to move through the landscape for a time equivalent to a month before the agents interacts with the environment and the subsequent processes of resource depletion and death are allowed to operate. This temporal lag builds up the memory of individual agents such that they do not succumb to death straight away based on the stochasticity of where they were ‘born’.

*Interaction:* Two types of interactions occur between the agent and the environment. The first interaction is whereby the environment influences the agent’s movements, and is underlined by the SSF model. The second interaction is where the agent’s movement influences the environment. If resource availability for the patch of environment the agent has moved into is greater than zero, then the fruit level will deplete for every time step it is occupied. Based on maximum values found in seed traps from Bosque et al. (1995) and the size of the fruit, it has been specified in the model that the agents can consume up to 20 pieces during one 10 minute time period (fruit consumption can be considered equivalent to energy). Each movement step can utilize up to 10 pieces of energy.

*Stochasticity:* All step lengths and turn angles are derived from empirical distributions obtained from the telemetry data. Equal interval frequencies of 20o bins were used to draw the turn angle value, with intervals of 100m for values between 0m and 1,000m, and intervals of 1,000m for values between 1,000m and 10,000m used to draw the step length. By using uneven interval frequencies, the possibility that unbalanced step lengths are selected is controlled, as these have been found to inflate coefficient values when used in SSF (Holloway & Miller 2014). Coefficients from the case-control regression model were used to model the likelihood that a step would be selected. The amount of energy gained from food consumption is potentially double that used of the energy used to move. Preliminary investigation of spatial simulation found that specifying equal energy gain and loss resulted in the death of all individuals almost immediately. This is obviously a subjective decision that could influence the results, which should be acknowledged, but a variant of a common assumption agent-based modelling (Wilensky 1997). To incorporate some stochasticity into this decision, these values were generated randomly up to the specified values, negating some of this potential bias.

#### ODD Initialization

Each simulation started with 1,000 oilbirds randomly placed in the study area and ran for a year. This population value was estimated based on the 90th percentile of observed oilbird populations in Venezuela (Herrera 2003). Land cover and vegetation presence was imported using the import.raster function. Empirical distributions of the turn angle and step length were imported as text files using the import function.

#### ODD Submodels

####  *Step-Selection Function*

 (A.5.1)

where βn is the coefficient estimated by the conditional logistic regression for the variable . The final model used is in Table A.5.1.

Table A.5.1: The results of the conditional logistic regression models used for step-selection function. \* significant at α < 0.1, \*\* significant at α < 0.05.

|  |  |
| --- | --- |
| Variables | Coefficient (Standard Error) |
| Evergreen Forest | 0.90630 (0.46580)\*\* |
| Cropland | 0.79150 (0.54720)\*\* |
| Rivers | -0.00020 (0.00004)\*\* |
| Memory | -3.11500 (0.97270)\*\* |
| Resources | -1.34000 (0.50440)\*\*  |
| Memory\*Resources | 3.39300 (0.98660)\*\* |

#### *Likelihood*

 (A.5.2)

#### *Death*

If an individual oilbirds energy drops below zero, then the oilbird dies.