**Electronic Supplementary Information**

Overview, Design Concepts and Details (ODD) for **NO*Rt*POPsurveillance.nlogo**

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**Background**

**NO**rway ***R****angifer* ***t****arandus* **POP**ulation **surveillance** (NO*Rt*POPsurveillance) model has been adapted from MO*Ov*POPsurveillance, an agent-based model simulating hunter-harvest based CWD surveillance in Missouri’s white-tailed deer populations. MO*Ov*POPsurveillance was designed with the objective of guiding the collection and analysis of disease surveillance data that relies on non-probabilistic methods like harvest-based sampling, and has been peer-reviewed and published (<https://doi.org/10.25937/8hpz-9y96>). Two papers describing application of this model have also been published [1,2].:

**Purpose**

NO*Rt*POPsurveillance is designed to simulate realistic snapshots of selected Norwegian reindeer populations and its annual harvest. Model iterations can be used to assess the efficiency of harvest strategies in removing CWD infected reindeer, especially in the early stages of the outbreak when CWD occurs at a very low prevalence and is difficult to detect.

**Entities, State Variables and Scales:**

*Entities*NO*Rt*POPsurveillancehas two entities: patches and reindeer. Reindeer are modeled as individuals occupying the patches. For this specific application, only the reindeer part of the model was used in this application.

*State variables*: Each patch is characterized by four state variables: *border* (whether it is a border or non-border patch), reindeer occupancy (*do*), mean reindeer density (*add*), and harvest pressure (*hp*) (Table 1). If desired, simulation of clustered distribution of CWD cases and/or non-random sampling for CWD surveillance is facilitated by the state variables *add* and *hp*. Not used for this application.

Each deer in the model has five state variables (Table 1), which define individual characteristics like age, sex, CWD infection status (*cwd*), whether the deer is marked for harvest (*marked-for-harvest*?), and whether a deer marked for harvest is also marked for sampling (*marked-for-testing?*)*.* In this application, we tested all harvested animals and assumed 100% test sensitivity.

*Spatial scale*: NO*Rt*POP*surveillance* landscape can be set up to represent one of the two Norwegian reindeer populations, Nordfjella Zone 1 (2000 km2) or Hardangervidda (8181 km2). Irrespective of the region selected for simulation, each patch in the model landscape represents one square mile.

*Temporal scale*: NO*Rt*POP*surveillance* runs for one time-step, representing one month when harvest is simulated.

**Table 1.** Agents and their state variables. All state variables except ‘aim’ are unitless. Variables of interest for the current application were Reindeer (except *aim*).

|  |  |  |
| --- | --- | --- |
| **Agent** | **Variable** | **Meaning/Value** |
| Patch | *border**do**add**hp* | edge patches have border = 1, other patches have border = 0reindeer occupancy, 1 if reindeer habitat, 0 if notmean reindeer density for a patch and its Moore neighborhood (8 neighboring patches)harvest pressure on a patch (0 is no harvest, 1 is low harvest pressure, and 2 is high harvest pressure) |
| Reindeer | *aim**sex**cwd**marked-for-harvest?**marked-for-testing?* | age in months male = 1, female = 0individual’s CWD infection status (infected = 1, uninfected = 0)individual marked for harvestindividual marked for testing  |

**Process overview and scheduling**

NO*Rt*POP*surveillance* implements three processes: individual growth, non-hunting mortality and hunting mortality with CWD testing.

*Schedule*: Growth (increase age by one month) of individuals is scheduled at the beginning of the time step, and is followed by non-hunting mortality and hunting mortality. Hunting mortality also includes CWD testing.

*Design concepts*

*Basic principles*.

NO*Rt*POP*surveillance* can simulate a realistic age-sex structured reindeer population. Further, CWD distribution heterogeneity (clustered distribution of CWD+ deer in the landscape, and/or age-sex class wise distribution of CWD cases) and sampling heterogeneity (or non-random sampling of deer) can also be simulated to account for real-world sampling biases.

*Stochasticity*: Reindeer mortality rates (natural and hunting) are deterministic, but individuals that die during a time step are chosen randomly. The distribution of CWD cases in the model population and selection of reindeer from hunter harvest are both stochastic processes.

*Observation*: NO*Rt*POP*surveillance* displays the total number of reindeer (male and female in each of the three age classes: calves, yearlings and adults), number of CWD+ reindeer in population (initial prevalence set by the user), number of CWD+ reindeer in the hunter harvest, and number of CWD+ reindeer in the sample (tested for CWD). If an alternate scenario (clustered\_dist) is selected, the graphical display highlights the area where CWD cases are clustered in the model landscape. Additionally, this information is also recorded in the output file *CWDsurveillanceNO*.

*Initialization*

NO*Rt*POP*surveillance* is initialized by selecting the desired reindeer population from the drop down menu (*sampling\_region* tab) and setting the reindeer population size and initial prevalence, using sliders provided on the model interface for each age-sex class.

*Submodels*

*1. Individual growth*

This submodel is executed at the beginning of the time step. All reindeer in the model landscape update their state variable ‘*aim*’ (age in months) by one month. Not used for this application.

*2. Non-hunting mortality*

The probability of a deer dying of natural or other non-hunting related causes during every time step is determined by age- and sex- specific monthly mortality rates. These rates are user-specified and set using the non-hunting mortality rate sliders provided on the model interface. Irrespective of these rates, old reindeer (>240 months) have an overall high probability of dying (0.8) during a time step.

*3. Hunting mortality*

Reindeer surviving the monthly non-hunting mortality execute the hunting mortality submodel. The probability of a reindeer being included in the hunter harvest is specified by the age- and sex- specific hunting mortality rates (Table 2).

In case non-random sampling (harvest) is to be simulated, patches with high average reindeer density (patch variable *add*) are designated as hunter-preferred patches. Reindeer are selected randomly for inclusion in hunter harvest in the baseline scenario; while in the alternate scenario ~50% of reindeer harvest occurs on hunter-preferred patches (non-random sampling). Further, the probability of testing harvested reindeer for CWD is specified by the observer using the ‘Percent harvest tested’ sliders for each age-sex class. The following counters for each age class-sex category are also updated: number of reindeer harvested on high/low/no harvest patches, CWD+ reindeer harvested, sample size, number of CWD+ reindeer in the harvest, and the number of CWD+ reindeer in the sample.

*Parameterization and Calibration* Population dynamics of the model reindeer population is defined by two sets of age-sex-specific parameters, *hunting mortality rates* and *non-hunting mortality rates*. We classify reindeer in three age-classes: calves (up to 12 months old), yearlings (13 to 24 months old) and adults (25 months or older). It should be noted that non-hunting mortality rates are per month rates while hunting mortality rates are annual (Table 2).

Additionally, user-specified parameters define the distribution of CWD cases in the model landscape, nature of sampling (random or non-random) and sampling intensity. The chooser *cwd\_distribution* specifies the distribution of CWD+ reindeer in the landscape: CWD+ deer are either randomly distributed throughout the model landscape (*random\_dist*), or are limited in distribution on a group of contiguous patches (*clustered\_dist*). Another chooser, ‘*sampling*’selects the sampling process, random or non-random sampling. Sample size for each age-sex class can be set using appropriate sliders on the interface (*%fawn-male-harvest-tested*, *%fawn-female-harvest-tested*, *%yearling-male-harvest-tested*, *%yearling-female-harvest-tested*, *%adult-male-harvest-tested* and *%adult-female-harvest-tested*).

**Table 2.** Age sex-specific baseline harvest rates for the Norwegian reindeer populations.

|  |  |  |
| --- | --- | --- |
| Parameter | Description | Value |
| *mf6hm* | male calves (< 12 months)  | 0.13 per year  |
| *ff6hm* | female calves (< 12 months)  | 0.13 per year  |
| *myhm* | male yearlings (13 - 24 months)  | 0.20 per year  |
| *fyhm* | female yearlings (13 - 24 months)  | 0.14 per year  |
| *mahm* | male adults (> 25 months)  | 0.20 per year  |
| *fahm* | female adults (> 25 months)  | 0.20 per year  |

**References**

 1. Belsare, A., Gompper, M., Keller, B., Sumners, J., Hansen, L. & Millspaugh, J. 2020 Size matters: Sample size assessments for chronic wasting disease surveillance using an agent-based modeling framework. *MethodsX* **online early**, 100953-

 2. Belsare, A. V., Gompper, M. E., Keller, B., Sumners, J., Hansen, L. & Millspaugh, J. J. 2020 An agent-based framework for improving wildlife disease surveillance: A case study of chronic wasting disease in Missouri white-tailed deer. *Ecol Modelling* **417**, 108919-