Appendix S1: Spatially explicit surveillance-data model for eradications

Biological Invasions manuscript: "Confirming the broadscale eradication success of nutria (*Myocastor coypus*) from the Delmarva Peninsula, USA"

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Calculating the probability of absence across the full extent

A virtual grid cell system is superimposed over the entire extent of interest (Anderson et al., 2013). The grid cell is the fundamental surveillance unit, so that the surveillance system is attempting to detect a residual nutria that has its homerange center in a particular grid cell. Given the very large area covered by the nutria eradication, the full extent is sub-divided into management zones, and a broadscale eradication approach is taken (Anderson et al., 2017).

The probability of absence given no detections at time t ($P\left(Absence|D^{-}\right)_t; orPoA$) is calculated using Bayes theorem:

$$PoA = P\left(Absence|D^{-}\right)_t = \frac{P\left(D^{-}|Absence\right)_t P\left(Absence\right)_t}{P\left(D^{-}|Absence\right)_t P\left(Absence\right)_t + P\left(D^{-}|Present\right)_t P\left(Present\right)_t} \quad (1)$$

where $P\left(D^{-}|Absence\right)_t$ is the specificity, $P\left(Absence\right)_t$ is the prior, $P\left(D^{-}|Present\right)_t$ is 1 - the system sensitivity (SSe) and $P\left(Present\right)_t$ is 1 - the prior. The specificity ($P\left(D^{-}|Absence\right)_t$) is increased to 1.0 (*i.e.* no false positives) because a potential positive detection would be confirmed as a presence of a Nutria. Assuming perfect specificity, Eq. 1 is reduced and rewritten as the following:

$$PoA_t = \frac{Prior_t}{1 - SSe_t(1 - Prior_t)}. \quad (2)$$

The prior is updated with each new session of surveillance as a function of the posterior (*i.e.* PoA_{t-1}) from the preceding session and a probability of re-invasion from the outside. The prior is updated as follows:

$$Prior_t = PoA_{t-1}\left(1 - PIntro_t\right) \quad (3)$$

where $PIntro_t$ is the probability of introduction (or re-invasion) at time t.

Calculating the system sensitivity (SSe) across multiple zones

The SSe is calculated as follows:

$$SSe = 1 - (1 - wtAveSeZ)^{P_z^*} \tag{4}$$

where $wtAveSeZ$ is the weighted average sensitivity across all zones and P_z^* is the number of *Occupied zones* (zone-level design prevalence; Cameron and Baldock, 1998). The number of *Occupied zones* is a statistical parameter that represents the number of zones that have residual nutria in them. It is not related to the actual number of occupied zones, but statistically defines what the surveillance system is trying to detect. Intuitively, it is easier to detect a surviving nutria if multiple zones were occupied than if a single zone was occupied. Because eradication is the goal, the P_z^* should be set to 1. The $wtAveSeZ$ is calculated as:

$$wtAveSeZ = \sum_{j=1}^{M} SeZ_j wt_j \tag{5}$$

where SeZ_j is the sensitivity for zone j, and wt_j is the weighting factor for zone j, and M is the total number of zones. The wt_j incorporates both habitat and historical risks at the zone level relative to all other zones, and is calculated as:

$$wt_j = \frac{\sum_{i=1}^{N_j} RR_{i,j}}{\sum_{j=1}^{M} \sum_{i=1}^{N_j} RR_{i,j}} \tag{6}$$

where N_j is the total number of cells in zone j, $RR_{i,j}$ is the cell level risk factor (*e.g.* due to habitat) in cell i and zone j. Zone specific historical risk factors that could be added to the $RR_{i,j}$, such as those due to control history or historical levels of presence.

We calculate the sensitivity in zone j (SeZ_j) as follows:

$$SeZ_j = 1 - (1 - wtAveSeZ_j)^{P_{u,j}^*} \tag{7}$$

where $wtAveSeZ_j$ is the risk-weighted mean unit sensitivity across all cells in zone j and $P_{u,j}^*$ is the number of *Occupied cells* in zone j (unit design prevalence). The $P_{u,j}^*$ is a statistical parameter like the P_z^* (eq. 4), but at the grid-cell level. The $P_{u,j}^*$ represents the minimum number of occupied cells that could reseed a population, and should be set conservatively low. The $wtAveSeZ_j$ is calculated as follows:

$$wtAveSeZ_j = \sum_{i=1}^{n_j} SeU_{i,j} wt_{i,j} \tag{8}$$

where $SeU_{i,j}$ is the unit sensitivity for cell i and zone j, n_j is the number of surveyed cells in zone j, and $wt_{i,j}$ is the risk weight for the corresponding cell. The $wt_{i,j}$ is calculated relative to all other cells in zone j:

$$wt_{i,j} = \frac{RR_{i,j}}{\sum_{i=1}^{N_j} RR_{i,j}} \tag{9}$$

where $RR_{i,j}$ is the relative risk value in cell i and zone j.

The $SeU_{i,j}$ is calculated as a function of the search effort of one or more detection devices and methods:

$$SeU_{i,j} = 1 - \prod_{k=1}^{K} (1 - SeU_{i,j,k}) \tag{10}$$

where $SeU_{i,j,k}$ is the unit sensitivity in cell i, zone j, and detection method k. Any detection methodology can be used, such as hair snares, traps, chewcards, dogs, cameras, people, tracking tunnels, public surveillance, etc. To reiterate, the fundamental surveillance unit is the grid cell, and the model is quantifying the probability of detecting a nutria that had its homerange in cell *i.* Therefore, a detection device or point can detect a nutria in the cell in which it is located or cells within its neighbourhood - depending on the homerange movement behaviour of the species (see below; Anderson et al., 2013; Efford, 2004; Ramsey et al., 2015).

In addition to point source methods, surveillance effort can be entered into the model in a raster grid format with binary data. Grid cells that received surveillance have a value of 1, otherwise a value of 0, which is applicable for public surveillance.

Calculating the cell sensitivity with point detection methods

The probability of detection of a nutria by a particular method and location, and the contribution that it makes to the sensitivity of a given grid cell will decrease with increasing distance between the point source and the grid cell. The probability of point detection method k (device/person/dog) detecting a nutria that has its home-range centre in cell i,j is calculated as:

$$P(capture)_{i,j,k} = 1 - \left(1 - g_0 exp\left(\frac{-d^2_{i,j,k}}{2\sigma^2}\right)\right)^{days} \tag{11}$$

where $d_{i,j,k}$ is the distance between a detection point k and cell i,j, g_0 is the probability of detecting a nutria if the device is placed at the animal's home-range centre , σ is the spatial-decay parameter for a home-range kernel (Efford, 2004), and *days* is the number of nights or days that a point method is set and checked. Consequently, the estimated search effort of a given detection point method for nutria in grid cells is assumed to decay spatially from the trap location with a half-normal kernel up to a maximum distance of 2 times the radius of a typical home range from the point (4σ).

References

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