Expansion and potential distribution of the hybrid Japanese knotweed (*Reynoutria bohemica*) and of the South African ragwort (*Senecio inaequidens*) in Aosta Valley (Northwestern Italian Alps)

A. von Hardenberg[1], D. Chabloz[2], F. Madormo[2], A. Mainetti[3], F. Pozzi[4], M. Bassignana[2]

[1] Conservation Biology Research Group, Department of Biological Sciences, University of Chester, Chester, UK; [2] Institut Agricole Régional, Aosta - I; [3] Gran Paradiso National Park (Consultant), Turin - I; [4] Institut Agricole Régional (Consultant), Aosta - I.

Introduction and Aims

All field samplings suffer from the problem of the *Imperfect Detection* (Guillera-Arroita, 2017), i.e. the problem of non-detection of a species in a site even if it is present.

Imperfect detection leads to **biases in species distribution models**, underestimating the real distribution, and to erroneous associations of the real probability of occupation of a site with environmental variables.

In order to contribute to a better understanding of the potential distribution of invasive alien plant species, we modelled the occupancy of the **hybrid Japanese knotweed** (*Reynoutria bohemica*) and of the **South African ragwort** (*Senecio inaequidens*) in Aosta Valley (Italy).

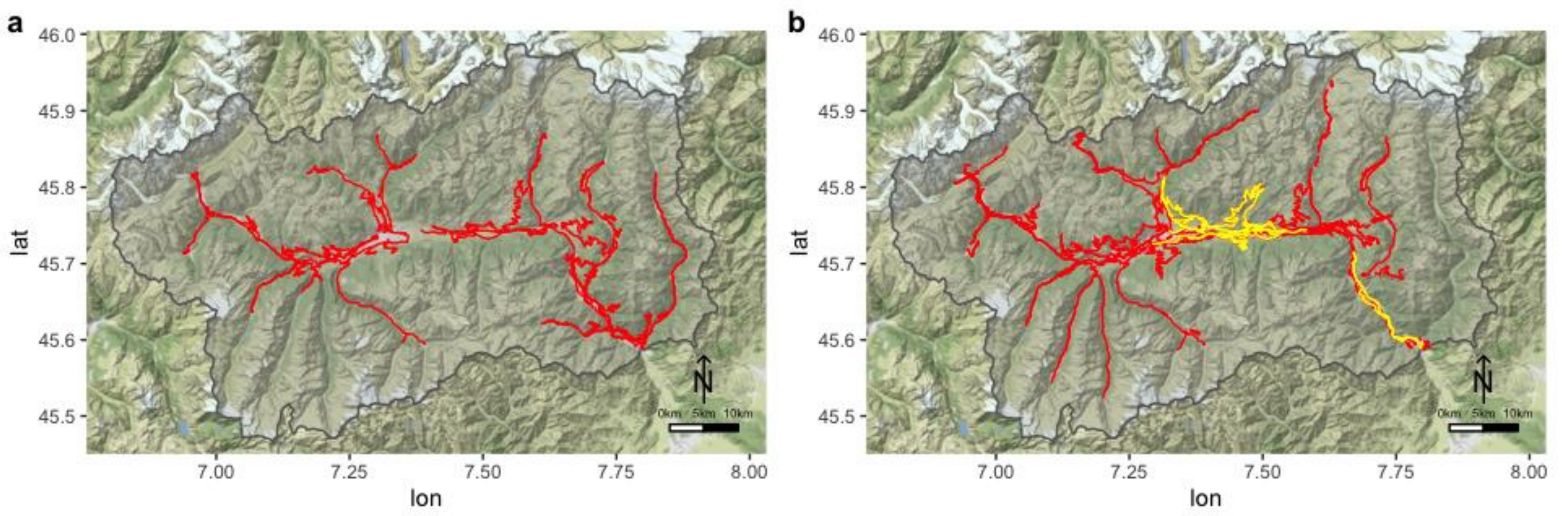

*Figure 1. Survey transects in Aosta Valley in 2010 **(a)** and in 2018 **(b)**. In yellow, the replicated transects for the estimation of the detectability.*

Materials and Methods

Field surveys

Eight transects were carried out in **2010** (Fig. 1a) and **60 transects** were carried out in **2018**, 16 of which were repeated twice to estimate the detectability (Fig. 1b).

The territory of Aosta Valley was divided in a **grid** of 500x500 m cells; the transects crossed 1090 cells in 2010 and 1475 in 2018.

Observation and site covariates

The survey **modality** (i.e. by car or on foot), the survey **date** and the **year** were included in our models as **observation covariates** potentially related to detectability.

For each cell the average **altitude**, its **slope** and **Northness** - calculated as cos(aspect) - the distance from the **nearest watercourse** and the percentage of **coverage of different habitats** were also considered as **environmental covariates** potentially related to occupancy.

Occupancy models

The **detectability** and **occupancy** of the two species were modelled by **single season occupation models** (MacKenzie *et al.*, 2003) using the R *unmarked* package (Fiske & Chandler, 2011). The data of 2010 and 2018 survey campaign were aggregated, assuming that the species detected in 2010 were still present also in 2018.

Models with different combinations of observation and environmental covariates were tested for each species and the **best model** was selected using the **Akaike criterion** (AIC; Akaike, 1974).

For each species, the occupancy was then **projected** over the entire territory of Aosta Valley, as a function of the values of the covariates present in the models in each cell using the *predict* function of the R *unmarked* package.

Results

Table 1 summarizes the total number of observations per species per year (n_{tot}), the number of cells with at least one observation per species per year (n_{cells}) and the estimate of the probability of naïve occupancy (ψ^; i.e. the occupancy obtained assuming a perfect detection). In addition, the estimates of the occupancy ($\psi(.)$) and of the detection ($p(.)$) in the absence of covariates obtained from the best models are also presented, as well as the estimate of the average occupancy predicted on the whole territory of Aosta Valley by the best model (ψ_{Pred}).

Species	Year	n_{tot}	n_{cells}	$p(.)$	$\psi(.)$	ψ^	ψ_{Pred}
Reynoutria bohemica	2010	323	99				
	2018	5401	123	0.71	0.1	0.08	0.02
Senecio inaequidens	2010	2369	306				
	2018	3728	123	0.39	0.45	0.27	0.12

Table 1. Occupancy and detection parameters of the two invasive alien species in Aosta Valley.

Hybrid Japanese knotweed (*Reynoutria bohemica*)

The best fitting model has a **constant probability of detection** (p=0.72, 95% CI=0.69-0.76). Occupancy is **negatively** related to the **altitude** (β=-1.48, SE=±0.2), the **Northness** (β=-0.26, SE=±0.13), the **slope** (β=-0.4, SE=±0.13), the percentage of **built-up areas** (β=-0.44, SE=± 0.1), the percentage of **agricultural areas** (β=-0.48, SE=±0.15) and the distance to the nearest **watercourse** (β=-1.27, SE=±0.34).

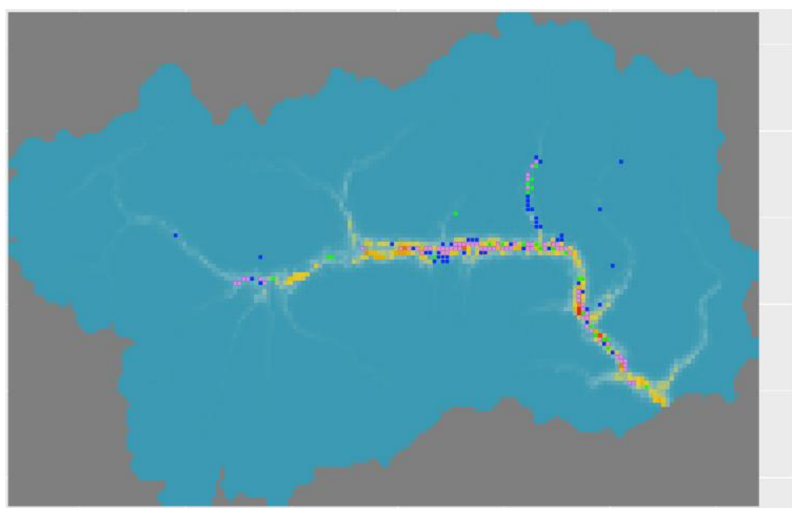

Figure 2. Field observations of Reynoutria bohemica *overlaid on its potential distribution map in Aosta Valley.*

*For both figures, the observations of the 2010 survey campaign are in **green**, the observations of 2018 are in **blue** and the cells with observations of the species in both survey campaigns are in **purple**; 'Predicted' is the predicted occupancy projected over the entirety of Aosta Valley.*

South African ragwort (*Senecio inaequidens*)

The best fitting model after the AIC selection procedure includes the **survey date** as the only variable that affects detectability (β=1.2, SE=±0.07). Occupancy is **negatively** related to the **altitude** (β=-0.88, SE=±0.09) while the **slope** (β=0.21, SE=±0.08) and the percentage of **xerothermophilous deciduous forest** present in the cell (β=0.35, SE=±0.09) have a **positive** relationship with occupancy.

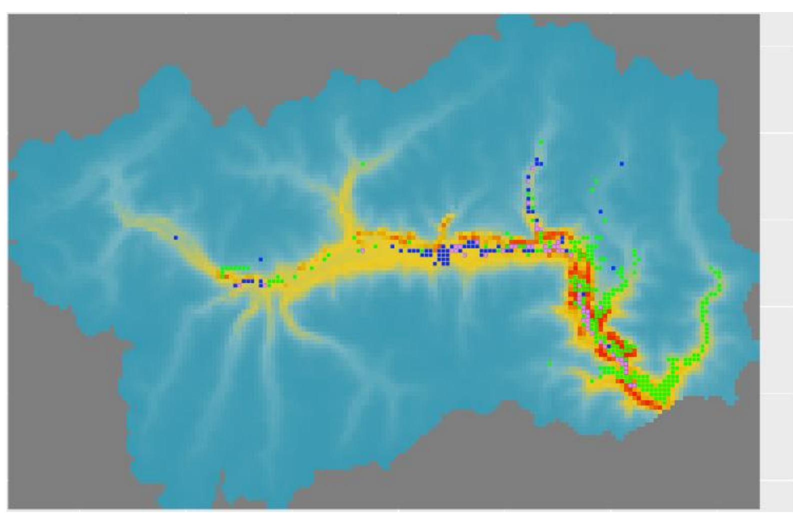

Figure 3. Field observations of Senecio inaequidens *overlaid on its potential distribution map in Aosta Valley.*

Discussion and Conclusions

For both species we found that **detectability** is less than 1, varying from **0.39** for *Senecio inaequidens* to **0.71** for *Reynoutria bohemica*. The less visible aspect of the former, particularly if not blooming, as well as the large size of the latter can reasonably explain these differences.

For *Reynoutria bohemica*, the best model has a constant detectability while for ***Senecio inaequidens*** the **detectability** varies with the **date**, probably depending on the inconspicuous aspect of the species when it is not in bloom.

As expected, **imperfect detection**, if not explicitly taken into account in the model, for both species has the effect of **underestimating occupancy**. The effect is particularly relevant for *Senecio inaequidens*, which has the **lowest detectability**, and for which the occupancy estimation goes from 0.27 (ψ^) to 0.39 (ψ) when detectability is included in the model.

The occupancy of **both** species **decreases** with **altitude**.

The presence of ***Reynoutria bohemica*** appears to be **positively** related to the proximity to **watercourses**, while the presence of **anthropized areas negatively affects** its occupancy.

The negative effect of agricultural areas on the presence of *Reynoutria bohemica* is probably explained by the fact that this particularly invasive species is kept under **active control** in farmland.

The selected models led to the creation of **potential distribution maps** over the entirety of Aosta Valley, identifying the areas at the highest **risk of expansion** and therefore optimizing the future **management strategies** of these invasive alien species on the regional territory.

References

Akaike, H. (1974). A new look at the statistical model identification. *IEEE Transactions on Automatic Control*, *19*(6), 716–723.

Fiske, I., & Chandler, R. (2011). Unmarked: An R package for fitting hierarchical models of wildlife occurrence and abundance. *Journal of Statistical Software*, *43*(10), 1–23. Retrieved from http://www.jstatsoft.org/v43/i10/

Guillera-Arroita, G. (2017). Modelling of species distributions, range dynamics and communities under imperfect detection: Advances, challenges and opportunities. *Ecography*, *40*(2), 281–295.

MacKenzie, D. I., Nichols, J. D., Hines, J. E., Knutson, M. G., & Franklin, A. B. (2003). Estimating site occupancy, colonization, and local extinction when a species is detected imperfectly. *Ecology*, *84*(8), 2200–2207.

Acknowledgments: this project was funded by the ERDF in the framework of the Interreg ALCOTRA Programme 2014-2020

RestHAlp+ · IAR · Parco Nazionale Gran Paradiso · Conservatoire d'espaces naturels Savoie · Interreg ALCOTRA · Fondo europeo di sviluppo regionale · UNIONE EUROPEA