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Research Article

Using habitat suitability models to scale up population persistence targets

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Abstract

Setting operational targets for the protection of species is crucial for identifying conservation priorities and for monitoring conservation actions' effectiveness. The use of quantitative targets for global species conservation has grown in the past ten years as a response to the commitment of reducing extinction rates established by the Convention on Biological Diversity. We reviewed the use of conservation targets in global scale conservation analyses, and found that most of the publications adopted species representation targets, corresponding to an amount of area to be protected. We found no work adequately targeting species' persistence, i.e. the complement to species extinction risk. Despite the adoption of pragmatic population targets, consisting in a number of individuals to be protected, has been recently proposed for global species conservation, the use of these targets at the species level is not always warranted. Pros and cons of using population persistence targets for species conservation have been discussed, yet the fundamental issue of how to scale these targets from populations to species is still unresolved. We discuss the process of "scaling up" population persistence targets to the species level using habitat distribution models, and test our approach in a case study on the European ground squirrel (*Spermophilus citellus*). We identified three main steps to be followed: *(i)* definition of a population target, *(ii)* characterisation of the species' populations by means of a habitat suitability model, and *(iii)* definition of a scaled species target. An up-scaled species target should include multiple conditions reflecting species persistence (number, size, location of the populations to be protected), uniqueness (e.g. evolutionary potential) and representativeness (e.g. presence in different ecosystems). Adopting scaled up species persistence targets within conservation planning approaches can allow protected area plans to give the highest contribution to reducing global species extinction risk.

Introduction

Conservation targets are quantitative estimates of the minimum amount of a particular biodiversity feature that should be included into a conservation plan (Pressey et al., 2007). Establishing conservation targets is necessary for evaluating the contribution of conservation actions (Margules and Pressey, 2000), and overall for reaching an explicit and accountable conservation decision-making (Carwardine et al., 2009). The efficiency of target-based planning with respect to other approaches, such as budget-constrained maximum-utility planning, has been criticized since it retains on average a lower fraction of species distributions for an equal investment (Di Minin and Moilanen, 2012). Nonetheless, target-based conservation is necessary to ensure that each biodiversity feature is adequately represented in a conservation plan, even when a feature does not overlap with others (as it may be the case for endemic species living in species-poor areas). Indeed, the use of quantitative conservation targets has grown in the past ten years in response to the commitment of reducing the rate of biodiversity loss, established by the Convention on Biological Diversity (CBD, 2010). While these targets should directly reflect the probability of persistence of a given biodiversity element (Pressey et al., 2007), the use of methods to set targets based on persistence probability is currently uncommon. The most common approaches to set conservation targets for species is the definition of a minimum representation area that is proportional to species' geographic range (Rodrigues et al., 2004a; Kark et al., 2009; Watson et al., 2011; Venter et al., 2014). This approach has been recently used to measure the irreplaceability of important biodiversity sites which have been identified over the past decades using semi-quantitative methods based on population thresholds (Di Marco et al., 2016a).

Global-scale conservation plans are typically focussed on species (Brooks et al. 2006), but populations are the units showing the most rapid response to threatening processes (Ceballos and Ehrlich, 2002). Therefore, conservation actions should be decided and evaluated in terms of the contribution they make to the persistence of a species' populations, and compared to pre-established targets. At the population level, conservation targets based on persistence probability were originally built on the concept of Minimum Viable Population (MVP), defined as the smallest isolated population having a high probability of remaining extant over a time period despite demographic, environmental (including catastrophes) and genetic stochasticity (Shaffer, 1981). However the MVP concept is still mostly theoretical and its application in conservation planning is problematic as Population Viability Analysis (PVA) relies on detailed demographic data, which are seldom available. MVP estimations always suffer from a certain amount of uncertainty, are context-specific, and may be particularly sensitive to range of observed data, thus estimations should be presented in terms of range of possible results or in the form of scenarios (Boyce, 1992; Reed

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et al., 2003). The discrepancy between the theoretical validity of the MVP concept and its practical application has been widely discussed (Traill et al., 2007). Due to limited data availability and rapid biodiversity decline, simplifications of the MVP concept have also been proposed (Brook et al., 2006). These include "pragmatic population viability targets" (Traill et al., 2010), and "equitable targets" (carrying capacity population sizes, reproducing and equal probability of persistence across species; Wilson et al., 2010).

The debate on using pragmatic targets for species persistence has risen in recent years, the main opposing arguments being based on the need of having readily available targets on the one hand (Traill et al., 2007, 2010; Clements et al., 2011) and on the shortfalls of setting universal targets on the other hand (Beissinger et al., 2011; Flather et al., 2011; McCarthy et al., 2011). Yet a fundamental question has been disregarded so far about how to properly scale up persistence targets from population level to species level.

In fact, using MVP or any of its surrogates as a species-level conservation target can be problematic. Species may be present as a network of populations with varying degrees of independence, and this may have great influence on conservation monitoring and gap analysis (Santini et al., 2014). Species persistence over time is influenced by a number of factors, such as number and size of the populations, connections among them, probability of extinction/colonization events, and distribution of threatening processes. Therefore species' extinction probability is a non-trivial combination of the extinction probabilities of each population (i.e. an aggregated risk of extinction) and mathematical and ecological considerations should be made case by case. As a minimum goal, conservation should aim at ensuring species' persistence, and conservation targets should reflect the elements necessary to estimate extinction probability. When detailed information on the spatial distribution of a species is not available, species distribution models can be used to represent habitat suitability for the species and to approximate the spatial distribution of individual populations.

Species distribution models are widely used in ecological and conservation research and, to some extent, for practical conservation applications (Guisan et al., 2013). There are two major families of distribution models (Rondinini et al., 2006): correlative models (inductive) and habitat suitability models (deductive). Correlative models rely on the ecological niche concept, and species distribution is predicted using the statistical relationships between the observed species distribution (presence-only or presence-absence points) and a number of environmental variables (Guisan and Thuiller, 2005). Suitability models instead adopt a mechanistic approach relying on the species-habitat relationships as derived from the existing literature and expert knowledge (Corsi et al., 2000; Rondinini et al., 2005). The notion of mechanistic models can also be extended to define "mechanistic niche models" (Kearney and Porter, 2009), where the knowledge of a species' physiological traits (e.g. thermal tolerance) allows to map its potential distribution in the environmental (e.g. with respect to temperature). Correlative species distribution models are used to predict the distribution of species of conservation concern (Engler et al., 2004) and invasive species (Václavík and Meentemeyer, 2012), and can be used to characterise changes in species ecological niche over time (Maiorano et al., 2013). Habitat suitability models are instead commonly used to refine coarse approximation of species distribution (geographic ranges) for regional (Boitani et al., 2007; Catullo et al., 2008; Beresford et al., 2011) and global (Jetz et al., 2007; Rondinini et al., 2011; Buchanan et al., 2011; Ficetola et al., 2015) analyses.

In this paper, we review the use of targets for global biodiversity conservation, discriminating between persistence and representation targets. We show that the vast majority of targets used in global analyses are not directly related to the notion of persistence, leading to potential uncertainty in the definition of global conservation priorities. We then build on the use of habitat suitability models to propose a simple framework to scale up population persistence targets to the species level and show its application in a case study on the European ground squirrel (*Spermophilus citellus*).

The use of quantitative targets for global species conservation

We searched the scientific literature for articles that use quantitative targets for species within the context of global-scale conservation analyses. It was not our purpose here to run an extensive review on the use of conservation targets (see Pressey et al., 2003; Rondinini and Chiozza, 2010), yet we aimed at providing a general overview of the quantitative targets currently used for global-scale conservation purposes. We run three search queries on the Scopus database (www.scopus.com), all of them being limited to works published between 2000 and 2015 in the "life science" area.

The first query searched for the terms "target*" AND "global*" AND "conservation plan*" in the title, abstract or keywords. The second query searched for the terms "global*" (in the title) AND "target*" (anywhere in the text) AND "conservation" (in the title, abstract or keywords). The third query searched for the terms "species" AND "target" in either title OR keywords, AND "biodiversity conservation" in the article. We then repeated the 3 queries by replacing "target*" with "objective*" or "goal*".

The search returned a total of 962 articles. We first excluded all publications not related to the use of conservation targets (not relevant for our analysis), and then combined the results of the queries into a database. We ended up with 175 publications, of which we considered 147 publications as non-relevant because: they did not mention any quantitative conservation target (n=75), they were actually local, national, or regional (not global) in their scope (n=44) or they only mentioned conservation targets without using them in an actual analysis (n=28).

Twenty six research papers (14.8%) used quantitative targets in global-scale conservation analyses (see Tab. 1 for a description). The vast majority of these works (92%) adopted area representation targets in various forms, while none of them proposed an up-scaling of population persistence targets for global species conservation. This result highlights a gap between local and global scale conservation plans, with the latter generally aiming at representing species distribution rather than targeting populations persistence. Additionally, representation targets are generally set arbitrarily, despite their crucial effects on the identification of conservation priorities (Vimal et al., 2011). While the identification of ecologically-meaningful representation targets is possible, this has been typically restricted to well-studied regions or species (Smith et al., 2008), where there was sufficient knowledge available to use species representation as a proxy of persistence.

The results of our literature review depict a scenario of partial disconnection between the aim of conservation planning, i.e. ensuring the persistence of biodiversity, and the way in which the vast majority of conservation targets are formulated, i.e. areal representations values. We thus present a method with which this gap can be reduced, by proposing the use of scaled targets of population persistence at the species level.

Scaling up population persistence targets to the species level

We follow Turchin (2003) in considering a population as a "group of individuals of the same species that live together in an area of sufficient size to permit normal dispersal and migration behaviour, and in which population changes are largely determined by birth and death processes". Often species are structured in metapopulations (Hanski and Gaggiotti, 2004), yet the metapopulation conditions are not always satisfied (Olivier et al., 2009; Mortelliti et al., 2010). These are therefore often referred to as "spatially structured populations" (Harrison, 1991). We will hereafter refer to "populations", also including spatially structured populations. We assume two "populations" to be separate if the connection amongst them, in terms of dispersing individuals, is negligible. An explicit consideration of the dynamics of spatially structured populations can enhance the definition of local and regional conservation plans (Akçakaya et al., 2007). Methods exist to scale up conservation priorities from local populations to spatially structured populations (McDonald-Madden et al., 2008), we step further from pre-

Table 1 – Description of the literature sources adopting quantitative conservation targets for global scale conservation analyses.

Target adopted	Aim of the analysis	Analysed features	Reference
Proportional representation area (fixed proportion)	Spatial conservation prioritization	Terrestrial mammals	Ceballos et al., 2005; Carwardine et al., 2008
	Planning protected areas expansion	Forests	Schmitt et al., 2009
		Forest birds	Buchanan et al., 2011
		Marine mammals	Pompa et al., 2011
	Evaluation of current target achievements	Important sites for biodiversity	Butchart et al., 2012
		Marine protected areas	Wood et al., 2008; Marinesque et al., 2012
		Biomes, Ecoregions, Realms	Brooks et al., 2004; Chape et al., 2005; Naidoo and Iwamura, 2007; Soutullo et al., 2007; Jenkins and Joppa, 2009; Underwood et al., 2009
		Countries	Nicholson et al., 2012
		Geophysical Diversity	Sanderson et al., 2015
		Carbon Storage	Larsen et al., 2014
	Quantification of costs to achieve the targets	Birds and other vertebrates	McCarthy et al., 2012
	Quantitative criticism to fixed area target	Vertebrates	Rodrigues et al., 2004b
Proportional representation area (varied proportion)	Gap analysis and identification of spatial priorities for PA expansion	Vertebrates	Rodrigues et al., 2004a
		Threatened vertebrates, Ecoregions (fixed target), Countries (fixed targets)	Venter et al., 2014
		Ecoregions (fixed target), IBAs, vertebrates, crayfish	Butchart et al., 2015
		Threatened Vertebrates, Ecoregions (fixed target)	Visconti et al., 2015
	Conservation prioritization analysis	Terrestrial mammals	Di Marco et al., 2012
Threshold population size	Comparison of target achievement and species threat status	Terrestrial mammals	Clements et al., 2011
Presence in at least one ecoregion	Spatial conservation prioritization	Carnivores	Loyola et al., 2009

vious considerations and propose the up-scaling of population persistence target to the species level.

The process of scaling up a conservation target, from population to species level, should account for three main steps (Tab. 2) aimed at ensuring species persistence through populations' protection: (i) setting the population target, (i) characterising the species' populations, and (i) setting the species target.

Step i — Setting the population target

The first step consists in setting a population target for the species. Defining a target in this context implies the identification of a particular number of individuals that is expected to persist over a certain period of time using one of the available methods. Existing examples include the estimation of MVP values (Brook et al., 2006), the use of empirical fixed population thresholds (Clements et al., 2011) and the calculation of equitable persistence target (Wilson et al., 2010). When the available information is sufficient, population-specific targets may be implemented to account for differential regional requirements. This would be particularly useful for species facing high heterogeneity in the environmental condition, a case that has sometimes resulted in the identification of MVP values that vary largely between populations of the same species (Flather et al., 2011).

It is not our purpose here to discuss the pros and cons of these and other methods, whose choice depends in any case on data availability and species characteristics. However we emphasise that setting conservative targets is desirable when population estimations suffer from substantial uncertainty.

Step ii — Characterising the species' populations

The second step consists in the characterisation of individual populations of a given species. This implies identifying the number of discrete populations likely to occur within a species' range and estimating their size, for example using habitat models in combination with density estimations.

The location of individual populations is well known for some species of conservation concern (e.g. the Lion, *Panthera leo*). In other cases, it may be possible to estimate the potential location of individual populations within a species' range by identifying clusters of suitable habitat, as shown in Santini et al. (2014). Patches of suitable habitat may form clusters if located within a pre-defined connecting distance. Each cluster may thus represent an individual population. This step is widely applicable for groups with available habitat suitability models, such as birds (Buchanan et al., 2011), mammals (Rondinini et al., 2011) and amphibians (Ficetola et al., 2015). The same approach can be applied to predictions based on correlative models; however, this approach would first require the setting of a probability threshold that dichotomizes the continuous probability of presence in presence-absences maps. This threshold can be set to minimise commission (i.e. false presence) or omission (i.e. false absences) errors, or balance between the two, in order to produce more/less conservative scenarios (Liu et al., 2005; Nenzén and Araújo, 2011).

Once the discrete populations are identified, the defined population target will be compared with the size of each individual population. Given that population size is unknown in most cases, a possible shortcut is to define a "potential population size", estimated from the size of suitable patches and the species' density, which is available for some species (Jones et al., 2009) and can be obtained through allometric relationship for others (Silva and Downing, 1995). This would allow for the identification of areas that are, at least potentially, able to sustain a population.

Step iii — Setting the species target

The third step is the definition of a global conservation target for the species, reflecting the overall species' conservation goal. While a numeric target (e.g. a MVP) can be directly used for population persistence, its use for species-level persistence is problematic, because this may result in splitting a MVP across multiple isolated populations. To scale up the target to the species level, entire viable populations must be considered. At one extreme, conserving one viable population of a species would prevent species' extinction within the prediction time frame; at the other extreme, conserving all viable populations would prevent losing any of them. A species conservation target should thus

Table 2 – Steps involved in the up-scaling of a population target to a species target.

Step	Output	Relevant factors
i. Definition of a population target	A minimum population size that would ensure persistence within a given time frame (MVP), depending on species' characteristics.	• life history traits • ecological species' dynamics • desired persistence probability
ii. Characterization of individual populations	Identification of the species' populations and their characteristics.	• spatial distribution • population size • spatial connections • population trend
iii. Definition of a species target	Number, location and size of the populations to be protected (species persistence). Additional factors may be included, related to species' uniqueness and spatial representativeness.	Persistence • aggregated risk of extinction Additional factors • evolutionary potential • taxonomic diversity • presence in different countries • functional diversity • exposure to threats

be defined between these two extremes. At a minimum, it should guarantee species persistence; ideally, it should include factors related to species uniqueness and representativeness (Tab. 2).

For example, if a synchronous decline related to a regional exogenous process (such as a widespread threat or a change in climate conditions) can affect all populations simultaneously, the minimum species target should be the protection of the healthiest (e.g. the largest) population. On the other hand, when the goal is more articulated (e.g. including considerations of taxonomy, geographic coverage and connectivity) this may be insufficient. For example, if the goal is to retain the maximum evolutionary potential of a species, at least one viable population of each subspecies, representing the species' evolutionary uniqueness, should be protected to improve species persistence of under forthcoming environmental changes (Ficetola et al., 2016).

Rather than a single number (e.g. a total population size), the target should thus be defined as a number of conditions to be met together, including a minimum size for each population (proxy for local persistence), and number and spatial distribution of the populations (proxy for extinction risk spread).

Case study: defining a conservation target for the European Ground Squirrel

We applied our proposed approach to a species with a relatively widespread distribution, characterised by fluctuations in abundance and occupancy and relatively short dispersal capabilities. We selected the European ground squirrel (*Spermophilus citellus*), a threatened species living in short-grass steppe and similar artificial habitats in south-eastern Europe, that is experiencing a serious decline with several local extinctions due to habitat loss and fragmentation (Hulová and Sedláček, 2008). Population structure ranges from inbred local populations in relative isolation from each other to typically spatially structured systems maintained by immigration (i.e. possible metapopulation or source-sink dynamics; Hoffmann et al., 2003; Matějů et al., 2010). Given the absence of an estimated MVP for this species, in the first step we adopted a value of 125886 individuals as a population target, averaged from two congeneric species *S. franklinii* and *S. tridecemlineatus* (available from Brook et al., 2006). Population density for this species is extremely variable, with 18–48 individuals per hectare usually found in optimal habitats (Hoffmann et al., 2003; Matějů et al., 2010). We conservatively assumed a density of 18 individuals/hectare (i.e. the minimum observed species density) to identify areas potentially able to support viable populations (minimum area target=70 km^2). In the second step, we used 1 km as the maximum dispersal observed for this species (Matějů et al., 2010) to detect isolated clusters of suitable habitat. We then used twice such distance in order to control for expansions/contractions of the local distributions due to habitat modifications (e.g. agricultural land abandonment). This reduces the chance of excluding unoccupied patches which can be easily reached by individuals belonging to two previously separate populations. We identified suitable habitat for this species according to Rondinini et al. (2011). The habitat suitability model could overestimate the species distribution if compared with atlas data from the Czech Republic (Matějů et al., 2010), but this is expected for highly fragmented populations subjected to local extinction in suitable areas. A paradigm of the metapopulation approach, however, is that empty patches must be conserved in order for the whole system to be viable (Hanski and Gaggiotti, 2004). Our goal in this case study was to ensure species' persistence in the face of habitat fragmentation. Therefore, in step (iii) our minimum target was to identify at least one area potentially able to sustain a viable population, while the optimal target was to select at least two main viable populations being close to other suitable areas, for potential future reconnection. Protecting two viable populations will augment the overall species persistence probability, and at the same time will augment the representation of species' range and the future chances of recolonization.

We detected over 17000 clusters of suitable habitat (>1 dispersal distance apart) among which 81 are potentially large enough to sustain a viable population (Fig. 1). Less than 2000 clusters were instead detected when adopting a double dispersal distance; in this case, the two main populations' blocks (i.e. occupying the two largest polygons in Fig. 1), that formerly encompassed several separate habitat clusters, appeared to encompass 2 main areas containing highly connected habitat. As a minimum target, we suggest to select at least one viable population within each of the two main range polygons; both of them contain in fact several possible target areas that could be potentially reconnected to each other, since most of the currently isolated habitat patches occur at a distance shorter than 2 km (a distance that this species could cover in a few generations). If resources allow, more than two populations should be selected, for example by employing an equal proportional coverage within each population block, to ensure a comprehensive coverage throughout the most connected portions of species range.

Selecting and maintaining one viable population within each of the two main polygons would be the best option, since it would ensure species' persistence within the two biggest and more connected portions of the species' range. Again, adopting a population target without upscaling it could be misleading for a species that is still globally present in good numbers yet faces a high risk of decline due to habitat fragmentation. By applying a non-scaled population target, such as the unconstrained representation of 10% of the species range (Rodrigues et al., 2004a), conservation efforts could be scattered amongst several unconnected (and possibly non-viable) populations in small habitat fragments, thus reducing the overall species' persistence probability.

Discussion

In this paper we used distribution models to propose a simple framework to scale up population persistence targets to the species level.

This is an alternative to the (common) use of species representation targets in conservation, which are unrelated to population persistence. We presented a practical application of our approach for the European ground squirrel, using habitat suitability models to characterise individual populations. The same exercise could be replicated using a correlative distribution modelling approach, and extended to different species with different levels of data availability. The proposed scaling up approach is necessary to avoid naive assignment of targets to species, as if they consisted in a single population. This becomes especially critical when focusing on species with low dispersal abilities and with a spatial structure consisting in many semi-independent populations.

The proposed identification of populations on the basis of suitable habitat and dispersal distance may lead to an over-estimation of population size. In fact, the implicit assumption of this approach is to consider suitable habitat as homogeneously occupied and population density and dispersal distance as an intrinsic features of the species, independent of local contexts. Population density and dispersal distance are indeed context-dependent parameters (Silva and Downing, 1995; Santini et al., 2013), and local barriers or disturbance factors can affect both. However, in large scale analyses it is likely that local variations are compensated, and assuming a mean constant value for the whole species distribution may be an acceptable approximation. In addition, the assumption of suitable habitat to be extensively occupied is less critical than assuming a completely occupied geographic range when assessing representation. Of course the assumption that habitat suitability is a good proxy for species occupancy can still represent an overestimation, particularly in those cases where a species is related to the presence of specific microhabitat conditions, unlikely to be represented in the satellite imagery used for building habitat models. Overall, several sources of uncertainty can influence the results, and a sensitivity analysis can be necessary to identify variables for which different scenarios should be considered.

Global and regional species conservation plans often aim at protecting a given proportion of species' distribution (see also Tab. 1), and are not directly related to species' persistence or populations characteristics. However, representation cannot be used as a direct measure of persistence if no consideration is given to the size required to ensure population viability and how different populations are located within a species' range. Consequently, the application of conservation targets directly related to species persistence is required. Targets aiming at ensuring persistence are intrinsically linked with populations and need to be properly up-scaled to be applied at the species level. Up-scaling a population target requires the identification of populations to which viability thresholds are applied. The spatial aggregation of the area to be protected is thus part of the target, and prevents the dispersion of conservation efforts across potentially non-viable populations in habitat fragments, that is often problematic in spatial prioritization exercises (Rodrigues et al., 2004a; Rondinini et al., 2005).

The simple application of representation targets across an entire species range, as currently done in many global analyses, is likely more problematic than scaling up population targets to the species level, regardless of the uncertainty in the data and methods used for the upscaling. For example, applying an unconstrained 10% representation target (Rodrigues et al., 2004a) could result in the identification of several unconnected, and possibly non-viable, fragments of ground squirrel populations (see "Case study"). Moreover, an explicit use of the uncertainty in parameter estimates can be done by testing different parameters combinations, each one representing different assumptions

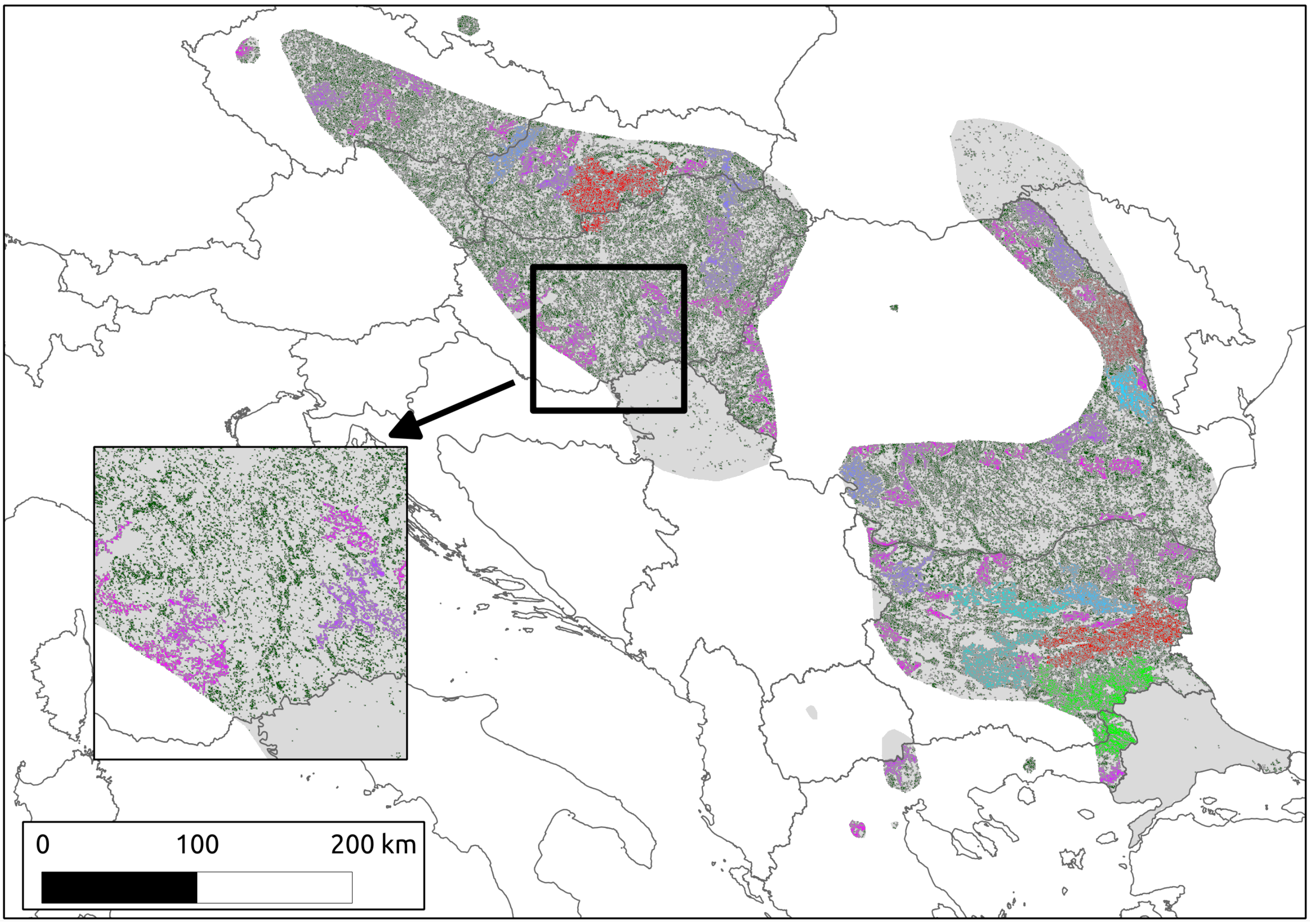

Figure 1 – Distribution range of *Spermophilus citellus*. Suitable habitat (coloured area) is surrounded by a potential dispersal matrix (shaded area) within the species range (in light grey). Areas smaller than the defined target area are reported in dark green, while clusters of suitable habitat larger than the target area are reported in random colours (with different colours indicating different clusters).

about key factors important for population and species persistence (e.g. minimum viable population size, dispersal distance, habitat type, population density, and threats dynamics). Explicit calculations of persistence probability could be made if all the required data are available, or decisions can be based on the characteristics of the populations and the distribution of ecological and threatening processes (when available data are limited). In both cases, relevant factors affecting the definition of a conservation target (Fig. 1) must be evaluated. Ideally, a target should go beyond the maintenance of a single viable population and should incorporate the maintenance of intra-specific variation, by preserving populations with distinct evolutionary characteristics, which ultimately act as a buffering mechanism against extinction (González-Suárez and Revilla, 2013).

Pressey et al. (2003) discussed the inappropriateness of fixed-threshold representation targets and proposed a mixed set of targets to be applied in the Cape Floristic Region, including number of locality records for plant and vertebrate species and population sizes for large mammal species. Santini et al. (2014) showed that disregarding the spatial structuring of species populations may lead to inequitable assessment of their conservation status, while the use of different measures of species dispersal had little effect on the final results. Representation targets are easy to implement, especially in situations when quick assessments need to be made and single metrics must be used for large optimization exercises (e.g. reserve planning). However, this ease of applicability could come at too high a cost, potentially resulting in a false sense of protection when the proposed target has been met by scattering the protection across several non-viable population fragments. Social, economic and political factors must be considered when identifying conservation priorities, in order to maximize the effectiveness of conservation actions (Wilson et al., 2010; Eklund et al., 2011). In addition, regional conservation plans can account for emergent properties of networks of conservation areas and local initiatives, including complementarity and connectivity. This is useful to explore alternative spatial configuration of regional reserve networks, yet an improved cross-boundary coordination is required to achieve effectiveness of these networks above the national scale (Santini et al., 2016). In this context, using our framework to define conservation targets for species can help moving from local scale actions to broader scale plans when a coordination of conservation interventions is required.

Population targets can improve the definition of conservation goals for species by approaching true biological needs, but they must be associated to other factors affecting species' persistence. We advocate that a species conservation target should consist in a number of conditions to be met in order to represent species' persistence, biogeography, and uniqueness. These should include the size, number and spatial distribution of the populations to be protected. Under the Convention of Biological Diversity (CBD, 2010), signatory nations face the challenge of implementing rapid and effective biodiversity policies. In particular, the CBD Aichi targets 11 and 12 imply the expansion of the global protected area network and the prevention of species extinction, which can be achieved synergistically (Di Marco et al., 2016b). Adopting species persistence targets within conservation planning approaches can allow protected area plans to give the highest contribution to the reduction of global extinction rates.

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