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Scale and conservation planning in the real world

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Conservation planning is carried out on a variety of geopolitical and biogeographical scales. Whereas considerable consensus is emerging about the most appropriate procedures for identifying conservation areas, the spatial implications of conducting conservation planning at divergent scales have received little attention. Here we explore the consequences of planning at different geopolitical scales, using a database of the mammalian fauna from the Northern Provinces of South Africa. The conservation network resulting from treating the region as one unit is compared with networks generated separately for the provinces nested in that region. These outcomes are evaluated in terms of (i) their land use efficiencies, (ii) their spatial overlap, and (iii) the impact of algorithm attributes. Although land use efficiencies are greater on broader scales, on average the spatial congruence between the broad-scale regional network and fine-scale provincial networks was <14%. Algorithms using different selection rules fail to improve this disturbing outcome. Consequently, scale has an overwhelming influence on areas identified as conservation networks in geopolitical units. This should be recognized in conservation planning.

Keywords: conservation networks; scale; spatial overlap; land use efficiency

1. INTRODUCTION

Biogeographical areas and geopolitical entities are seldom congruent. The boundaries for the distributions of species do not respect those of nation, state or province. This poses a major constraint on effective planning for the conservation of biodiversity. In isolation, such planning would best be performed on the basis of biogeographical units (thereby rendering immigration a second-order process), with areas of high and low priority for conservation action (e.g. strict reservation, restrictions on land use and agreements with land owners) being recognized within their bounds. However, practical decisions about land use are actually carried out at the level of geopolitical units, that is at the level at which legal and administrative instruments operate.

Geopolitical units are typically organized hierarchically, with decision making in many areas of the world being progressively devolved to units of smaller geographic extent (Commission on Global Governance 1995). The trend is paralleled by calls for the greater involvement of local communities in conservation planning (Holdgate 1994; McNeely 1994). This raises the question of how the level in the geopolitical hierarchy at which such planning is performed influences the spatial configuration of those areas that are designated as priorities for conservation. At one extreme, the conservation areas recognized may be identical, regardless of whether analyses are carried out across broad regional geopolitical units or across the small local units of which they are comprised, in which case it essentially does not matter at which level this is done. At the other extreme, the areas recognized may be entirely different, such that areas regarded as being important by regional analyses are not those regarded as being such by local analyses. In this case, decisions either have to be made about the most appropriate level of analysis based on other criteria or some multiscale approach has to be employed. We explore the spatial implications of determining conservation areas at different spatial scales by identifying such areas for mammals for nested geopolitical units in South Africa.

2. METHODS

An established data set (Freitag *et al.* 1996) of primary distribution data for 199 mammal species occurring in four provinces of South Africa was used. This data set has been previously used for investigating the limitations and characteristics of conservation area selection procedures (Freitag & Van Jaarsveld 1995, 1997, 1998; Freitag *et al.* 1996, 1998*a*,*b*; Van Jaarsveld *et al.* 1998). For the present study, the data set was expanded to include comprehensive data from Gauteng, Mpumalanga, Northern Province and Northwest provinces (figure 1). These data represent recent records and more closely

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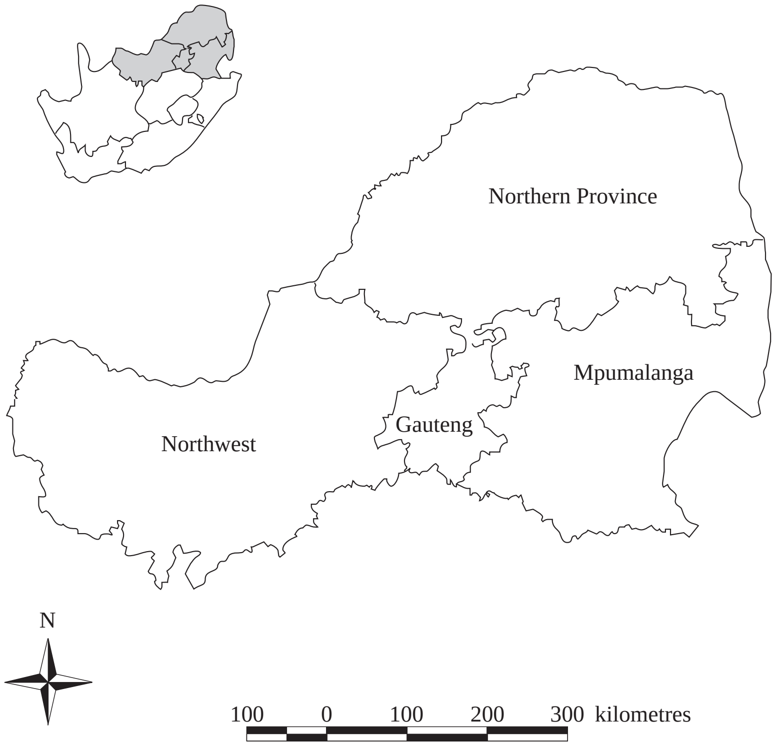

Figure 1. Map of the study area.

represent the area of occupancy of species than generalized distribution maps (see Gaston 1991; Freitag & Van Jaarsveld 1995; Freitag *et al.* 1996). These were generalized to 15 mile × 15 mile grid cells (*ca.* 25 km × 25 km) as presence–absence maps. Potential conservation areas were subsequently identified using five complementarity-based algorithms (Nicholls & Margules 1993; Freitag *et al.* 1997), which identify a near-minimum set of areas to represent all of the species at least once. The algorithms prioritized regionally occurring species using different criteria (data set rarity, relative endemicity (RE), *Red data book* (Smithers 1986) vulnerability (RV), regional occupancy (RO) and taxonomic distinctiveness (RTD)) and selected areas in a sequence to maximize stepwise gains using these criteria (Freitag *et al.* 1997). Data set rarity refers to the frequency with which a species is observed in the data set.

$$\mathrm{RE} = \frac{\text{distribution area within region under consideration}}{\text{total distribution area}}. \quad (1)$$

$$\mathrm{RO} = \frac{1}{\sqrt{\text{no. of grid cells occupied in distribution data set}}}. \quad (2)$$

RV is based on *Red data book* listings for species. Non-listing in the *Red data book* was awarded a value of zero, with the categories indeterminate, rare, vulnerable and endangered scoring 0.25, 0.5, 0.75 and 1, respectively.

$$\mathrm{RTD} = \frac{1}{\sqrt{f \times g \times s}}, \quad (3)$$

where f is the number of regionally represented families in the order, g is the number of regionally represented genera in a regionally represented family and s is the number of regionally represented species in a regionally represented genus.

The values for each of these four criteria range between zero and one and are similarly distributed (Freitag & Van Jaarsveld 1997).

The algorithms differed in their initial and subsequent selection rules and, consequently, in the spatial configurations generated (Freitag *et al.* 1997). Each algorithm was first employed for each of the provinces (within-province results) and then across all four provinces as a whole (across-province results). Minimum-set, complementarity-based algorithms are recognized as providing the most efficient heuristic solution to the maximal covering problem (Camm *et al.* 1996; Church *et al.* 1996); the results are not guaranteed of being optimal, but the differences are expected to be small and the calculations have the advantage of speed for interactive analyses (Csuti *et al.* 1997; Williams *et al.* 1996; Pressey *et al.* 1997).

The spatial consequences of employing algorithms at different scales was assessed in terms of land use efficiency and the degree of spatial overlap (Pressey & Nicholls 1989; Van Jaarsveld *et al.* 1998). Efficiency (E) is expressed as

$$E = 1 - x/t, \quad (4)$$

where x is the number of grid cells selected and t is the total number of grid squares that contain data records.

$$\text{Spatial overlap (Jaccard coefficient)} = X/(A + B - X) \times 100, \quad (5)$$

where X is the number of grid cells shared in a province, A is the number of additional grids selected for a provincial network and B is the number of additional grids selected for the broad-scale network in the same province.

The role that attributes of the area selection algorithms play in determining this scale-related pattern was also examined. The land use efficiency and degree of spatial overlap between the across-province networks and the alternative within-province networks were determined for networks selected using different algorithms. The algorithms use either rarity, taxonomic

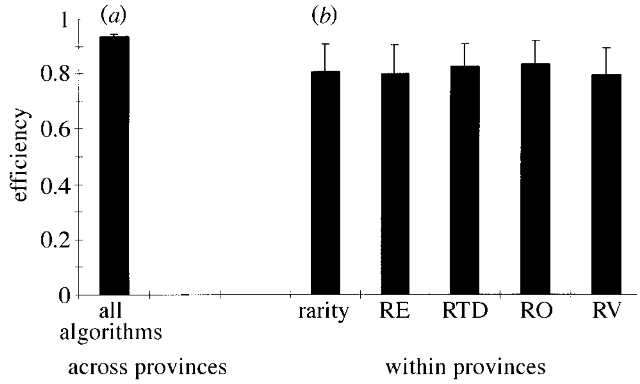

Figure 2. Mean land use efficiencies of conservation areas identified (*a*) across provinces using assorted algorithms ($n = 5$; Nicholls & Margules 1993; Freitag *et al.* 1997), and (*b*) employing assorted algorithms within different provinces ($n = 4$): rarity, data set rarity algorithm (Nicholls & Margules 1993); RE, relative endemicity algorithm; RTD, relative taxonomic distinctiveness algorithm; RO, relative occupancy algorithm; RV, relative vulnerability algorithm (Freitag *et al.* 1997).

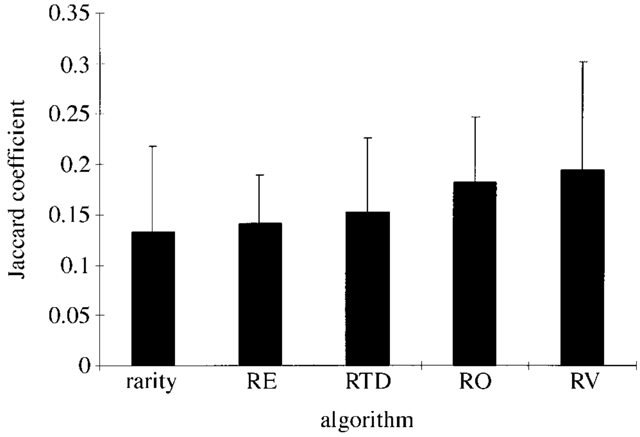

Figure 3. The degree of spatial overlap of within-province ($n = 4$) conservation areas with an across-province conservation network using an assortment of algorithms: rarity, data set rarity algorithm (Nicholls & Margules 1993); RE, relative endemicity algorithm; RTD, relative taxonomic distinctiveness algorithm; RO, relative occupancy algorithm; RV, relative vulnerability algorithm (Freitag *et al.* 1997).

distinctiveness, relative endemism, area of occupancy or vulnerability as their initial selection rules. These various selection rules are known to affect the spatial configurations generated and, consequently, the networks selected (Nicholls & Margules 1993; Freitag *et al.* 1997).

In addition, the land use efficiency of initially employing an across-province network or, alternatively, the within-province network was assessed. This was conducted by pre-selecting (Freitag *et al.* 1997) sites identified as conservation areas at the across-province scale, followed by the addition of within-province requirements. This outcome was compared to the reverse of this process: adding across-province requirements to sites identified using within-province analyses. These comparisons were conducted for each of the five algorithms.

3. RESULTS

Conservation land use efficiencies were high (Pressey & Nicholls 1989) on both the across- and within-province scales, requiring on average some 20% of the total land area to represent all mammal species at least once (figure 2). Nevertheless, the percentage of land required is markedly smaller, by the non-trivial factor of three, on the across-province scale (within-province mean = 19.6% and range = 11.5–34.2% and across-province mean = 6.6% and range = 5.0–7.4%).

More significantly, the degrees of overlap between the particular areas identified on the two administrative scales are extremely low (figure 3). The degree of overlap in each province between the across-province analyses and those recognized within provinces was <14% (mean = 13.2% and range = 2.7–22.9%). To a large extent, this is simply because areas which receive a high priority on the within-province scale do so on the basis of species which are relatively scarce at this level, but these species are not necessarily scarce across the four provinces as a whole.

The use of alternative algorithms for selecting conservation areas did not improve either land use efficiency (figure 2*b*) or the degree of spatial overlap between across-province and the finer-scale within-province networks (figure 3). Little algorithm-related variation in land use efficiency was evident (figure 2) although the use of different algorithms uniformly generated some variation in overlap (figure 3). However, this was not sufficient to explain the consistently low overlap between the across- and within-province networks. Consequently, we cannot ascribe the low degree of spatial overlap to attributes of any particular algorithm chosen and scale appears to be the dominant contributing factor to this spatial variation.

Moreover, regardless of whether conservation area selection was conducted on an across-province scale, pre-selecting those areas selected and then adding the outstanding within-province requirements or reversing this approach had little effect on mean land use efficiency (both *ca.* 20%; figure 4). However, this multiscale approach may increase the total area that ultimately needs to be conserved, from below to above 20% in the present study (compare figures 2 and 4).

4. DISCUSSION

The failure of across-province and within-province conservation areas to show marked overlap means that areas identified on one scale will have to be explicitly recognized and addressed in planning on a different scale. For example, species that are rare within provinces play a disproportionate role in determining the locality of those within-province conservation areas that are selected and may be of immense significance to the local human communities living there (Hunter & Hutchinson 1994). However, these species may not be conserved in those same provinces when implementing conservation area networks designed on broader scales. It seems likely that this result will generalize widely, with broad implications for the application of and techniques for the selection of conservation areas. These techniques are increasingly finding practical application (Pressey *et al.* 1995, 1996) in highlighting the best options for designing conservation

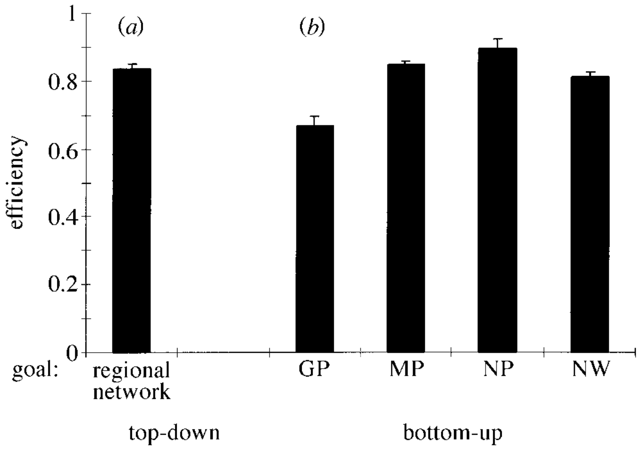

Figure 4. The comparative land use efficiency of (*a*) preselecting across-province networks prior to adding additional provincial requirements using assorted algorithms ($n=5$; Nicholls & Margules 1993; Freitag *et al.* 1997) or (*b*) reversing this process by selecting within-province networks prior to adding across-province requirements ($n=5$).

networks and the implications of employing alternative networks (Faith & Walker 1996). However, to date, the implications of scale referred to here have not been systematically incorporated in conservation area selection procedures (Csuti *et al.* 1997; Williams *et al.* 1996; Freitag & Van Jaarsveld 1997).

There are both virtues and shortcomings of a parochial approach towards determining conservation priorities (Hunter & Hutchinson 1994). The shortcomings include skewed fund allocation and overemphasis on peripheral populations. The virtues include maintaining local genetic diversity, local ecosystem function and local human values, using umbrella species to conserve local taxa, the administrative mandates of conservation organizations and the use of locally threatened species as management–experimental models to prevent population declines (Hunter & Hutchinson 1994). Whatever the balance of virtues and shortcomings, this conservation reality is likely to persist.

The outcome of the results reported here suggests that a multiscale approach to designating conservation areas may be appropriate. Just as frameworks aimed at combining regional and global extinction risks for assessing the conservation status of individual species are being considered (Avery *et al.* 1995; Freitag & Van Jaarsveld 1997), such frameworks for identifying conservation areas should be developed. Significant obstacles to doing so may be posed by variation in the geopolitical levels to which conservation planning is devolved in different nation states.

The more encouraging outcome is that the sequence in which this multiscale approach is pursued appears less important, as it makes little difference to ultimate land use efficiencies (figure 4). However, adopting a multiscale approach may marginally increase the total area required for conservation. Naturally, this assertion requires further investigation.

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