# Identification and evaluation of priority conservation areas for Buprestidae (Coleoptera) in South Africa, Lesotho, Swaziland and Namibia

H.E. Hull[1*], S. Freitag[2], S.L. Chown[1] & C.L. Bellamy[3]
[1]*Department of Zoology and Entomology, University of Pretoria, Pretoria, 0002 South Africa*
[2]*Scientific Services, South African National Parks, Private Bag X402, Skukuza, 1350 South Africa*
[3]*Transvaal Museum, P.O. Box 413, Pretoria, 0001 South Africa*

Representative priority conservation areas of quarter-degree grid size (approximately 25 × 25 km) were identified using an iterative rarity-based algorithm for the beetle family Buprestidae (Coleoptera) in South Africa, Lesotho, Swaziland and Namibia. This algorithm provided similar results (number of grids chosen, grid identity and efficiency) to an algorithm that based selection of areas on the taxonomic distinctiveness of each species. The algorithms were also run after pre-selecting grids containing buprestid records and at least 25, 50, 75 and 100 % protection in the form of established reserves, and the number of additional grids required to adequately represent all species was determined. The existing reserve network was found to be inefficient for the conservation of Buprestidae, although many records fall into grids within or containing protected areas. The Nama Karoo, Northern Cape savanna, and grassland are evident as areas of least known richness owing to undersampling. When the algorithms were run for the entire study area, considerably fewer grids, as well as a different spatial arrangement of grids, was selected within Namibia, but not within the combined regions of South Africa, Lesotho and Swaziland. This illustrates possible asymmetry when sharing conservation responsibilities between nations.

**Key words**: Coleoptera, Buprestidae, priority conservation areas, iterative algorithms.

## INTRODUCTION

Invertebrates comprise the bulk of global species richness, and the loss of invertebrate species will constitute much of the loss of biodiversity (New 1993; Samways 1994; New & Yen 1995; Scholtz & Chown 1995). These potential losses are of concern because invertebrates are known to render significant ecological services in terrestrial and aquatic systems (Janzen 1987; Kremen *et al.* 1993; New 1993; New & Yen 1995). In addition, they may be used as effective bio-indicators of environmental change (Janzen 1987; Kremen *et al.* 1993; New 1993; Kremen 1994; New & Yen 1995; Weaver 1995). It is particularly in their role as bioindicators that invertebrates have received increasing attention in conservation issues over the last decade in terrestrial (Kellert 1993; Kremen *et al.* 1993; Launer & Murphy 1994; Samways 1994) as well as aquatic ecosystems (Kellert 1993; Samways, 1994). Nonetheless, in broad-scale terrestrial conservation planning, insects have scarcely been considered.

In southern Africa, only two studies have sought to investigate the areas required for conservation of insect taxa (Freitag & Mansell 1997; Muller *et al.* 1997), compared with many investigations of the areas required for conservation of vertebrate taxa (Branch *et al.* 1995; Drinkrow & Cherry 1995; Gelderblom & Bronner 1995; Gelderblom *et al.* 1995; Lombard 1995; Mugo *et al.* 1995; Skelton *et al.* 1995) and the efficacy of the methods used to select these areas (Freitag & Van Jaarsveld 1995; 1997; Freitag *et al.* 1997). All the invertebrate studies have focused mainly on soil-dwelling insects and, to date, no studies have examined the distribution of phytophagous insects and the identification of priority areas that would be required to conserve them, although phytophages represent the highest proportion of terrestrial insect species (Lawton & Strong 1981). Information on this functional group of insects is of importance if priority areas are to be selected on the basis of maintaining

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*To whom correspondence should be addressed:
e-mail: hehull@zoology.up.ac.za

ecosystem functioning and not simply species richness (Noss 1990; Pickett *et al.* 1992; Walker 1992), and the likelihood of congruence of priority conservation areas for this group and others, such as soil insects and vertebrate taxa, is to be determined. The latter is of particular importance because of the unique land-claims situation that is likely to influence the future of South African conservation (Khan 1990; Scholtz & Chown 1993). The past positioning of conservation areas has resulted in serious mistrust and suspicion among local people owing to the concomitant legacy of land dispossession and forced removals (Khan 1990; McNeely 1994). Khan (1990) and Scholtz & Chown (1993; 1995) have suggested that the land question is the biggest stumbling block to the implementation of conservation objectives in South Africa. In this context, as well as that of declining resource allocations to conservation (DEAT 1996), there is an urgent need for efficient, strategic methods for the identification of priority conservation areas in southern, and particularly South Africa (Rushworth 1997).

In the invertebrate context, New (1993) argued that the investigation of conservation priorities for systematically well-assessed groups of invertebrates is likely to be more rewarding than that for poorly-known taxa. In southern Africa, the butterflies (Lepidoptera) represent the phytophagous insect group that is systematically best known (Pringle *et al.* 1994). Butterflies, however, represent only one or at the most two of the feeding types characteristic of herbivorous insects (Strong *et al.* 1984), and are currently being investigated with regard to priority area selection (Muller *et al.*, unpubl.). The present study therefore investigated geographic variation in species richness, and the selection of priority conservation areas for the jewel beetles (Coleoptera: Buprestidae). This is a systematically well-assessed family of phytophagous wood-boring, stem-boring, leaf-mining or free-living root-feeding beetles that are abundant in southern Africa (Holm & Bellamy 1985). Very little is known of the biology of most buprestid taxa, except that they are among the most thermophilic insects known, and the larval stages are often prolonged compared to those of the adult (Holm & Bellamy 1985). In addition, some groups are thought to have very close associations with plant taxa on which they oviposit and feed (Gussmann 1994).

## MATERIAL AND METHODS

Because the selection of priority conservation areas based on species richness has been shown to be highly inefficient in southern Africa and elsewhere (Kershaw *et al.* 1994; Freitag & Van Jaarsveld, 1995; Williams *et al.* 1996), iterative selection procedures were used in this study (Kirkpatrick 1983; Bedward *et al.* 1992; Margules *et al.* 1994). By incorporating the principle of complementarity, these methods offer the advantages of efficiency, explicitness and flexibility (Nicholls & Margules 1993; Margules *et al.* 1994; Williams & Humphries 1994). In addition, the initial selection procedures may be altered by, for example, first selecting rare or endemic species or unique habitats, species-rich areas, regions rich in endemics (Van Jaarsveld 1995), or taxonomically distinct taxa (see Vane-Wright *et al.* 1991; Crozier 1992; Faith 1992; Williams & Humphries 1994; Freitag & Van Jaarsveld 1997; Freitag *et al.* 1997).

In this study, priority conservation areas were determined for selected buprestid species from the combined countries of South Africa, Lesotho and Swaziland, and from Namibia, using two iterative algorithms reflecting the qualities of rarity and taxonomic distinctiveness. These two major regions were examined both separately and in combination to determine whether the efficiency and identity of area selection for either region changed with changing geographic extent. Since conservation actions ultimately depend on political decisions (Scholtz & Chown 1993), and because these are likely to be determined by financial constraints, it is important to determine whether regional collaboration in conservation is likely to provide benefits to all countries participating in such actions, or whether these benefits are likely to be asymmetrical (Hunter & Hutchinson 1994).

Lesotho and Swaziland were included in the analyses for South Africa because they are small countries relative to the scale of analysis and comprise a geographically continuous unit with South Africa (Gelderblom & Bronner, 1995). The number of records obtained for these countries was also too small to facilitate separate analysis.

Data were obtained from specimens in the Transvaal Museum, Pretoria, South Africa (TMSA), and from published literature (Kerremans 1913; Ferreira & Ferreira 1959a,b; Jelinek 1971; Holm 1974, 1979, 1982, 1985, 1986a,b; Bellamy & Holm 1985a,b, 1986; Bellamy

1986a,b,c,d,e, 1987, 1988a,b, 1989a,b, 1991, 1996a,b; Bellamy & Scholtz 1986; Bellamy *et al.* 1987; Holm & Gussmann 1991, 1992; Volkovitsh & Bellamy 1992; Gussmann 1994; Holm & Schoeman, unpubl.). Localities on specimen labels, and those provided in the literature usually lacked quarter-degree grid references or map coordinates. These localities were therefore mapped on the relevant 1:50 000 maps. Data were entered as latitude and longitude coordinates, and generalized to quarter-degree grid squares (15′ × 15′, *ca* 25 × 25 km). Higher taxonomic rank, date of collection, collector, and institution in the case of data obtained from literature, were also recorded. Museum accession numbers were unavailable in most cases, and were not recorded. In an attempt to restrict the data to recent information, records before 1900 were disregarded, even if they were the only record for a particular species.

The major constraints encountered with museum material were imprecise labelling, such as missing dates and collectors, and undocumented localities. When locality coordinates could not be ascertained, records were discarded. Localities, given only as grid-square references in the literature and in museum data, that could not be found on maps, were assigned to the centre point latitude and longitude in question. When localities were given as distances from a town or landmark, they were measured along a road in the stated direction.

Area selection was undertaken using two iterative algorithms to determine which would provide the most efficient network of priority areas: (1) the rarity-based algorithm of Nicholls & Margules (1993) and, (2) the taxonomic distinctiveness algorithm of Freitag *et al.* (1997). Taxonomic uniqueness or distinctiveness (TD) was calculated for each species in the database using the index from Freitag & Van Jaarsveld (1997), modified by additional categories in the taxonomic hierarchy so that

$$TD = \frac{1}{\sqrt{SF \times T \times ST \times G \times SG \times SP}}$$

where $SF$ = subfamily, $T$ = tribe, $ST$ = subtribe, $G$ = genus, $SG$ = subgenus and $SP$ = species. Calculations were performed by multiplying the number of species in a particular subgenus by the number of subgenera within the genus by the number of genera within the subtribe by the number of subtribes within the tribe by the number of tribes within the subfamily by the number of subfamilies within the family for each species. Thus, the higher the score, the more unique the species, and the higher its priority for conservation based on this index.

Algorithms were first implemented on data for each region without mandatory sites, and subsequently with mandatory sites which have either 25 %, 50 %, 75 %, or 100 % of their total area included in conservation areas (*e.g.* National Parks, Game Reserves, but excluding private reserves). The procedure was then repeated for all regions combined. This was carried out to determine whether the network of grids comprising the priority areas generated by the algorithms differed substantially from the present protected area system. Because the number of grids that can ultimately be selected for conservation is likely to be limited by economic and other considerations, a primary aim in reserve selection must be to represent all attributes in as small an area as possible (Kershaw *et al.* 1994). This is known as efficiency (E) (Pressey *et al.* 1993) and is calculated as

$$E = 1 - \frac{X}{T}$$

where $X$ is the number of grids selected by the algorithm, and $T$ is the total number of grids in the region under consideration (Pressey *et al.* 1993). Area selection networks should ideally aim for a high degree of efficiency ($E \approx 1$). The Jaccard coefficient of similarity was used to quantify the degree of spatial overlap between area networks at different levels of pre-selection (Freitag & Mansell 1997; Muller *et al.* 1997).

Maps of species richness and selected area network were produced using the Geographic Information System REGIS™ (Autodesk Africa, Centurion, South Africa).

## RESULTS

Data for 609 species, in three subfamilies, 24 tribes, 27 subtribes, 97 genera, 125 subgenera, and at 1648 localities in 930 grids were used in these analyses. This includes a number of species from the TMSA that have not yet been named but which have been numerically designated by one of us (CLB). There are many species (167) with only one record, but it cannot be concluded that these are all endemic, merely that they are 'database' rare.

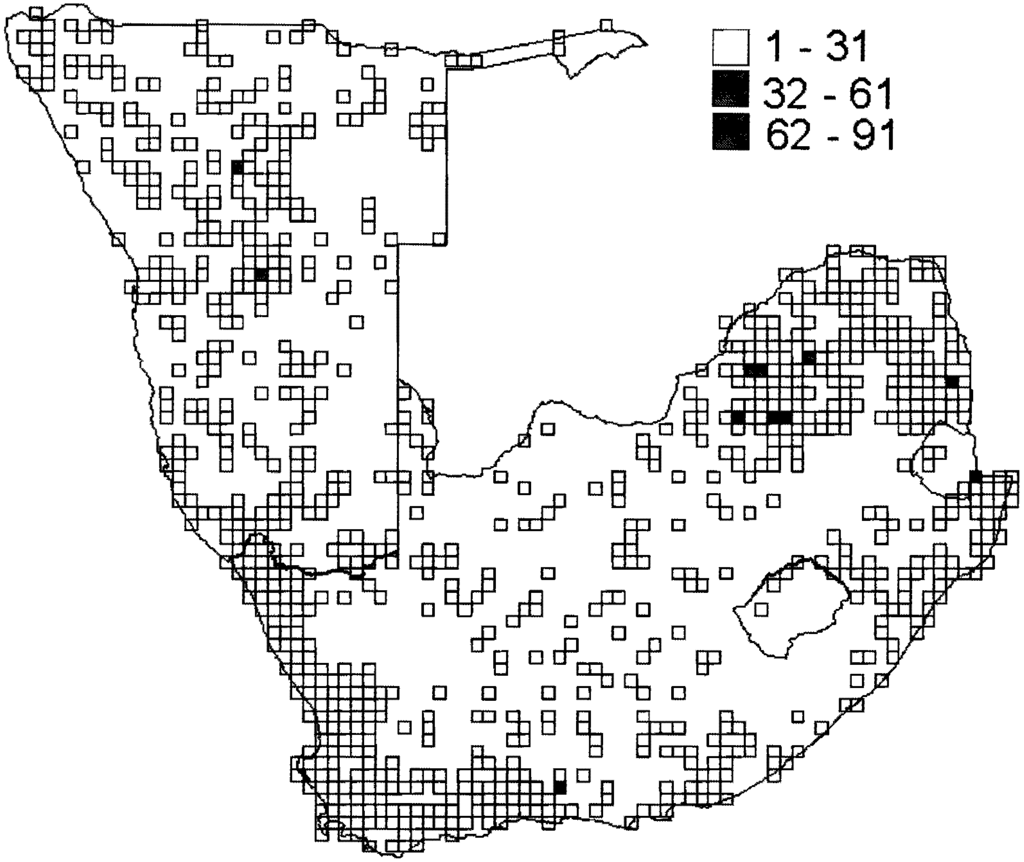

**Fig. 1.** Richness of Buprestidae species in quarter-degree grid squares for South Africa, Lesotho, Swaziland and Namibia combined.

These species are relatively evenly distributed across the study region.

The number of grids chosen using the rarity and taxonomic distinctiveness algorithms were very similar. In addition, the degree of spatial congruence between networks selected by these algorithms was high, thus only the results obtained from the rarity algorithms are considered further.

Buprestid species-richness for the quarter-degree grid squares is shown in Fig. 1. To represent each species in the database at least once, 133 grids (out of a total of 2013) were chosen by the rarity algorithm for the South Africa region, 41 (out of 1251) for Namibia, and 146 (out of 3240) for all regions combined (Table 1, maps of these grids shown in Figs 2–4). Algorithm outputs including pre-selected grids were always less efficient than those where no pre-selection was undertaken. However, since this difference in efficiency was very small (lowest value 0.910, highest value 0.934), we examined the number of grids required in addition to those that were pre-selected (Table 1). The highest number of additional grids were required at the 100 % pre-selection level, with fewer grids being required with decreasing levels of grid pre-selection (Table 1). Fewest grids were required when no pre-selection constraint was implemented. These trends were consistent for both regions examined separately as well as for the combination of regions. Spatial overlap of grids was highest when selection was undertaken without pre-selection of grids compared to where grids with 100 % of their area comprised some form of conservation were pre-selected (Table 2).

**Table 1.** Number of grids chosen (GR), number of additional grids chosen (other than the protected grids) for the algorithms using pre-selected grids (EX), and efficiency (EFF) for the algorithm results for the rarity algorithm (RA) for the combination of South Africa, Lesotho and Swaziland, Namibia and all regions combined. The suffixes 25, 50, 75, 100 pertain to the percentages of pre-selection used in the rarity algorithm. The number of grid cells present in each area of study are in brackets.

| Algorithm | South Africa, Lesotho and Swaziland (2013) | | | Namibia (1251) | | | Combined regions (3240) | | |
|---|---|---|---|---|---|---|---|---|---|
| | GR | EX | EFF | GR | EX | EFF | GR | EX | EFF |
| RA | 133 | | 0.934 | 41 | | 0.967 | 146 | | 0.955 |
| RA25 | 182 | 106 | 0.910 | 104 | 30 | 0.917 | 265 | 113 | 0.918 |
| RA50 | 160 | 124 | 0.921 | 92 | 34 | 0.926 | 228 | 132 | 0.930 |
| RA75 | 151 | 128 | 0.925 | 75 | 36 | 0.940 | 201 | 137 | 0.938 |
| RA100 | 141 | 131 | 0.930 | 68 | 37 | 0.946 | 183 | 141 | 0.944 |

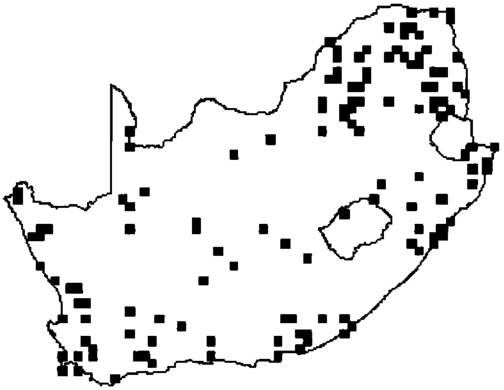

**Fig. 2.** Priority conservation areas selected for Buprestidae in South Africa, Lesotho and Swaziland using the rarity algorithm.

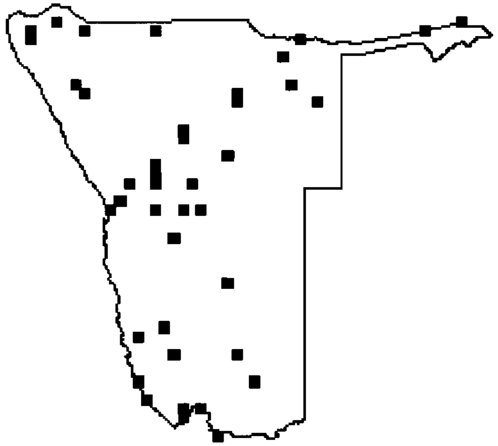

**Fig. 3.** Priority conservation areas selected for Buprestidae in Namibia using the rarity algorithm.

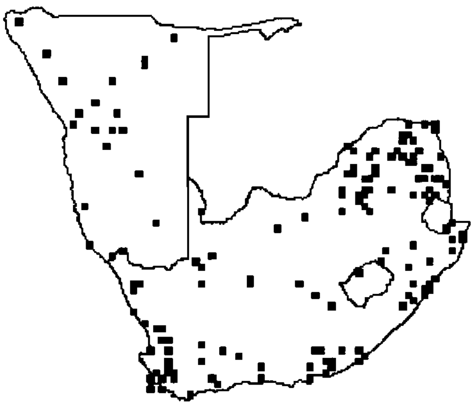

**Fig. 4.** Priority conservation areas selected for Buprestidae in South Africa, Lesotho and Swaziland and Namibia using the rarity algorithm.

Fewer grids were needed to achieve full representation of species in both regions when the algorithm was implemented on the combination of all regions than when each region was considered separately, which resulted in a higher efficiency for each of the two constituent regions. This was more marked for the Namibia region (21 grids compared to 41) (Table 1; Figs 3,4), than for the South Africa region (125 grids compared to 133). The difference also extended to a different spatial arrangement of grids for both regions – relatively large for Namibia (44 % spatial overlap between grids selected for the region on its own compared to when combined with the South Africa region), but relatively small for the South Africa region (83 % spatial overlap).

**Table 2.** Jaccard coefficients of similarity between algorithms run for South Africa, Lesotho and Swaziland, for Namibia, and for all regions combined. RA = rarity algorithm, RA25, RA50, RA75, RA100 = algorithms run with a pre-selection of 25, 50, 75 and 100 % protected grids respectively.

| | RA25 | RA50 | RA75 | RA100 |
|---|---|---|---|---|
| South Africa, Lesotho & Swaziland | | | | |
| RA | 74.453 | 93.233 | 96.503 | 98.693 |
| RA25 | | 79.688 | 77.273 | 75.556 |
| RA50 | | | 96.875 | 94.656 |
| RA75 | | | | 97.710 |
| Namibia | | | | |
| RA | 73.171 | 78.571 | 83.333 | 85.714 |
| RA25 | | 88.235 | 83.333 | 81.081 |
| RA50 | | | 94.444 | 91.892 |
| RA75 | | | | 97.297 |
| Combined Regions | | | | |
| RA | 68.182 | 87.838 | 91.034 | 92.617 |
| RA25 | | 77.536 | 74.825 | 72.789 |
| RA50 | | | 96.350 | 92.308 |
| RA75 | | | | 95.804 |

## DISCUSSION

The taxonomic distinctiveness and rarity algorithms use different species-based selection criteria (Freitag *et al.* 1997). Nevertheless, in this study, similar grids were chosen as priority areas using these two algorithms (Jaccard coefficient = 88.967 %). In contrast to these results, Muller *et al.* (1997) concluded that the performance of the taxonomic distinctiveness algorithm was more efficient than the rarity algorithm, selecting only half the number of grids for full representation. One of the major differences between the termite study of Muller *et al.* (1997) and the buprestid database used here, was in the number of species included and the numbers of distribution records per species. In the termite study of Muller *et al.* (1997) there was a relatively small number of species compared to the numbers of records per species, while the buprestid dataset contains many species with a relatively small number of records per species. This suggests that the prioritization of species conservation by assigning taxonomic distinctiveness scores may result in a more efficient network of priority areas for conservation when there is a relatively large number of records per species. Additionally, a dataset with a relatively large number of records compared to species may result in a more flexible, efficient resultant reserve network.

Kershaw *et al.* (1994), Freitag & Mansell (1997), Muller *et al.* (1997) and Freitag *et al.* (1998a) all stated that when established protected areas were included in the priority area networks chosen by reserve selection algorithms, the number of grids required for achieving representativeness increased. The same result was obtained in the present study. This is indicative of the inefficiency of the present southern African conservation network in representing Buprestidae. Some species are represented many times in some reserves (which is not unfavourable), while some reserves do not include any known Buprestidae records at all, although this may be due to survey bias.

It is acknowledged that areas identified as having high or low species richness (hotspots and coldspots) may merely reflect biased collection efforts (Gentry 1992). Examples of such areas are: hotspots in close proximity to major towns, cities or research institutions (Gelderblom & Bronner 1995; Freitag *et al.* 1998b), and/or coldspots in regions of poor sampling (Drinkrow & Cherry 1995; Gelderblom *et al.* 1995). This is evident here, with many records occurring in grids containing major cities or towns or in areas that are known to be favoured by collectors. For example, the richest grid east of Pretoria (93 species), and the grids including Thabazimbi (35 species) and Rustenburg (36 species) all contain popular areas for collectors from the Transvaal Museum. Skukuza (34 species) is well-collected because it is the administrative centre for the Kruger National Park and Nylsvley (41 species) is the site of a longterm savanna research programme (Whittaker *et al.* 1984). Likewise, Windhoek (44 species) is the capital and largest city in Namibia, and has the country's only museum and university. A further reason for cities and towns showing up as apparent hotspots is due to old data that were collected before large-scale development of these areas.

Like many other priority area selections, this analysis shows that several areas important for the conservation of these Buprestidae species are under-represented in the national reserve networks of South Africa, Lesotho, Swaziland and Namibia. Of particular significance in this context are the alpine grassland areas (Siegfried 1992; Preston & Siegfried 1995), particularly of Lesotho, the Nama Karoo biome (Siegfried 1992; Drinkrow & Cherry 1995; Gelderblom *et al.* 1995; Mugo *et al.* 1995; Freitag & Mansell 1997), the Northern Cape savanna, the Western Cape renosterveld, and the succulent Karoo (Siegfried & Brown 1992; Drinkrow & Cherry 1995; Mugo *et al.* 1995; Freitag & Mansell 1997). Areas in Namibia that are in need of protection include the southern semi-desert region, and the northern and eastern semi-desert and savanna areas. In many instances these areas (and those that are represented in the protected area network) are under considerable threat. For example, Dean & MacDonald (1994) noted that stocking rates have increased in many areas of the Northern Cape savanna. Similarly, although stocking capacities in the Karoo have decreased, which may suggest that the land is carrying the maximum capacity of livestock, it is more likely that forage plant productivity has decreased, indicating degradation of these rangelands, desertification and irreversible changes in the diversity and abundance of Karoo vegetation (Dean & MacDonald, 1994). Likewise, only small areas of pristine Renosterveld remain (Huntley 1989), and locust control programmes are having adverse effects on non-target species in the Karoo (Horne, pers. comm.). Conservation threats in the fynbos and savanna biomes have been well documented (Huntley 1989; Scholtz & Chown 1993; Rushworth 1997).

Conservation agencies and Natural History museum staff in South Africa seem to regard many of the above biomes as relatively low conservation priority areas. A survey conducted in these institutions by Preston & Siegfried (1995) found that, of the terrestrial systems, both the Nama and Succulent Karoo, montane grassland and desert systems were near the bottom of a list of conservation priorities. In this context, our results confirm that the poor management practices of farmers and developers, are also likely to have a detrimental impact on insect and, particularly, buprestid faunas.

The large differences in the spatial positioning and numbers of grids selected for Namibia when the rarity algorithm was employed for this region alone, and in combination with the South Africa region, as well as the absence of such a pronounced difference for the latter region is of considerable significance. It suggests, first, that the South African region may have a greater number of endemic, or range-restricted buprestid species compared to Namibia. However, this apparent range restriction is impossible to ascertain from the data collected for most of these beetles, and may be a false signal generated by the lack of data for many species. This emphasizes the need for additional surveys, particularly in undersampled regions of southern Africa (Kremen *et al.* 1993; Drinkrow & Cherry 1995; Freitag & Mansell 1997).

Second, the differences in spatial positioning also provides an indication that the advantages of conservation collaboration to participating countries may be rather asymmetrical. Collaboration between the two major regions in the study might substantially reduce the number of conservation areas required for a single representation of each buprestid species in Namibia. In addition, South Africa, with the highest population density, greatest extent of land transformation, and most polemical land claims debate (Khan 1990; Scholtz & Chown 1993), would appear to benefit least from such a collaboration, given that very few additional areas in South Africa could be used for non-conservation purposes if conservation networks were to be assigned in collaboration with Namibia. As a consequence of this and of the different conservation strategies adopted by countries (*e.g.* different priorities, financial constraints), it appears that selecting areas on a country by country basis may be the most reliable conservation strategy in southern Africa.

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