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# Systematic conservation planning: a review of perceived limitations and an illustration of the benefits, using a case study from Maputaland, South Africa

Robert J. Smith, Peter S. Goodman and Wayne S. Matthews

**Abstract** Systematic conservation planning is widely considered the most effective approach for designing protected area and other ecological networks. However, many conservation practitioners still ignore these methods and we suggest that five perceived limitations of this process are affecting its uptake. These perceptions are that (1) systematic conservation planning software is difficult to use, (2) the process requires extensive biodiversity distribution data, (3) setting targets for representing conservation features is not possible, (4) the advantages of systematic conservation planning do not outweigh the costs, and (5) the resulting plans often identify unsuitable areas. Here we review these perceived limitations and argue they are all misplaced, although we recognize difficulties in the target setting process. We then illustrate the value of systematic conservation planning to practitioners using a case study that describes a low-cost exercise from Maputaland, South Africa. This preliminary conservation assessment measured the effectiveness of the existing reserve system and identified a number of candidate areas that could be the focus of community- or privately-run ecotourism or game ranching ventures. Our results also emphasize both the importance of producing planning outputs that are specifically targeted for stakeholders, and the role of systematic conservation planning in providing a framework for integrating different provincial, national and transnational conservation initiatives.

**Keywords** Conservation planning, ecological networks, implementation, Maputaland, protected areas, South Africa.

## Introduction

Most reserve networks fail to conserve important biodiversity elements (Pressey, 1994) and a variety of planning techniques have been proposed to improve this situation. One such approach is systematic conservation planning, which is a target-driven process for designing reserved systems and other ecological networks. It involves working with a range of stakeholders to (1) set broad conservation goals for a planning region, (2) map valued conservation features, (3) set numeric targets for how much of each conservation feature should be protected, (4) identify where new conservation areas should be established to meet these targets, and (5) develop an implementation strategy for achieving results (Margules & Pressey, 2000). The process of identifying new areas, together with measuring existing levels of protection, is called a conservation assessment (Knight *et al.*, 2006). This generally involves using specific conservation planning computer software to identify reserve networks that meet representation targets whilst minimizing costs. Many conservation assessments are based on minimizing the area of the reserve network but a range of more relevant socio-economic and threat data are also increasingly used (Wilson *et al.*, 2005).

These planning techniques are generally now considered the most appropriate for designing reserved networks (Pressey & Cowling, 2001) but this has not resulted in widespread uptake by practitioners (Prendergast *et al.*, 1999; Jackson *et al.*, 2004; Knight *et al.*, 2006). Use of these techniques is largely restricted to Australia, South Africa, North America and projects undertaken by several non-governmental organizations (Pressey, 1999; Balmford, 2003). Here we argue, based on a review of the literature and our experience of working with a number of conservation practitioners, that five perceived limitations of systematic conservation planning are preventing greater uptake. We argue that all of these five perceptions are incorrect, and we

**Robert J. Smith** (Corresponding author) Durrell Institute of Conservation and Ecology, University of Kent, Canterbury, Kent CT2 7NR, UK.
E-mail R.J.Smith@kent.ac.uk

**Peter S. Goodman** Biodiversity Research Division, Ezemvelo KwaZulu-Natal Wildlife, PO Box 13053, Cascades 3202, South Africa.

**Wayne S. Matthews** Tembe Elephant Park, Ezemvelo KwaZulu-Natal Wildlife, Private Bag 356, Kwangwanase 3973, South Africa.

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illustrate the value of this approach with a case study from Maputaland, South Africa, where a low-cost planning exercise has been used to inform land-use decisions on the ground.

## Five perceived limitations of systematic conservation planning

### *Perception 1: Systematic conservation planning software is difficult to use*

Most conservation assessment exercises use specifically designed computer software to import, analyse and display the relevant data. This can act as a significant barrier, as any reluctance or inability to use these programmes will prevent their further use (Prendergast *et al.*, 1999). A short-term solution is to employ consultants to undertake this computer-based work but conservation plans need to be continually updated to stay relevant (Meir *et al.*, 2004) and this depends on each planning organization having the appropriate capacity. Moreover, planning processes are probably most effective when institutionalized within the organizations responsible for implementation (Driver *et al.*, 2003). Fortunately, a number of user-friendly software packages, such as *CLUZ, C-Plan* and *MARXAN*, have been developed recently (Ball & Possingham, 2000; Ferrier *et al.*, 2000; Smith, 2004) and anyone with a basic knowledge of geographical information system (GIS) software can learn to use these programmes without additional training, although the long-term effectiveness of this process will depend on the development of appropriate organizational systems and support.

### *Perception 2: Systematic conservation planning requires extensive biodiversity distribution data*

Developing conservation plans requires fine-scale biodiversity distribution data to delineate boundaries of proposed protected areas and other conservation areas. Unfortunately, few maps that show the distribution of species throughout the planning region are available at this scale, even for countries with a long tradition of data collection (Oldfield *et al.*, 2004; Pressey, 2004). However, this does not mean that systematic planning methodologies cannot be applied. For example, a number of assessment exercises have used coarse biodiversity surrogates, such as broad vegetation types, and produced useful results. Moreover, more detailed land cover types can be mapped by people with the relevant expertise using low cost satellite imagery and this information, when combined with freely available elevation data and relevant species distribution data, can provide a valuable basis for any planning exercise (Cowling *et al.*, 2004; Pressey, 2004).

### *Perception 3: Setting targets for representing conservation features is not possible*

Systematic conservation assessments are based on setting representation targets for each conservation feature and any resultant output will be strongly affected by these values (Svancara *et al.*, 2005) because more habitat is needed to meet higher targets. These targets should ensure that each feature persists into the long-term and the most well known approaches use minimum viable population size to estimate the habitat requirements of key species (Cabeza & Moilanen, 2001). In addition, recent work has developed target setting methodologies for land cover types based on their species richness (Desmet & Cowling, 2004), and this is particularly relevant given the dependence of most fine-scale analyses on this type of data. It is likely, however, that conservationists will have to set targets based on limited knowledge and that these targets may change as new information is incorporated into the system (Pressey *et al.*, 2003). This will inevitably lead to controversy if advocates for conflicting land uses focus on the inherent uncertainty of setting targets and question the validity of the resultant conservation plans. Thus, planners should emphasize that targets are a vital part of conserving biodiversity but that they may change with increasing knowledge and changing conservation goals, and should equate the process to other forms of adaptive management, with the need for further research to resolve disputes.

### *Perception 4: The advantages of systematic conservation planning do not outweigh the costs*

Systematic conservation planning involves a number of time-consuming stages (Margules & Pressey, 2000; Knight *et al.*, 2006) and therefore some practitioners may prefer simpler techniques based on small expert groups identifying important areas (Prance, 1990). However, all of these extra steps can increase the value of the planning process (Pressey, 1999). For example, increased expert participation helps build consensus, increases the number of conservation features incorporated into the assessment, allows targeted surveying to fill information gaps, and captures information in a way that can be shared and stored (Driver *et al.*, 2003). Similarly, holding workshops to set conservation targets and to develop implementation strategies allows involvement of different stakeholders, building support for the final system and increasing transparency (Knight *et al.*, 2006). In addition, systematic conservation assessments generally identify networks that conserve biodiversity more efficiently than other methods. This is because they use complementarity-based approaches and predefined representation targets, thus reducing the opportunity for including deliberate or unconscious trade-offs at early stages in the planning process (Pressey & Cowling, 2001; Cowling *et al.*, 2003).

### *Perception 5: Systemic conservation plans identify unsuitable areas*

The theoretical basis of systematic conservation planning has greatly benefited from collaborations between conservation practitioners and academics, producing methods that are both relevant and scientifically defensible. However, a number of methodological, institutional and financial constraints have influenced the academic community's input, so that: (1) Some academic research focuses on topics that are not considered important by practitioners (Pressey *et al.*, 1996; Prendergast *et al.*, 1999). (2) Some research topics require extensive species distribution data sets that are rarely available at the fine-scale, and therefore many researchers use more readily-available broad-scale data sets instead; however, the resultant analyses tend to measure existing levels of protection inaccurately (Araújo, 2004) and may misidentify priority areas (Lennon *et al.*, 2001). (3) Some analyses focus on one aspect of scientific theory and, for simplicity, use arbitrary values for every other aspect of the assessment; for example, it is common for assessments to use the same target value for every species mapped in the planning region (Pressey, 2004), thus implicitly assuming they have the same conservation importance and ecological requirements. All three of these constraints make it likely that many conservation assessments published in the scientific literature include areas known to have low conservation importance by local practitioners. Thus, there is a risk that practitioners judge the value of the systematic conservation planning approach based on their opinions of these academic-driven assessments, without being aware of the constraints. Therefore, it is vital that practitioners understand the role of theory-based articles in the scientific literature, and that the authors of these articles are careful when describing the purpose of their work.

## The value of systematic conservation planning: a case study from Maputaland

We believe that the benefits of systematic conservation planning outweigh the costs and that these techniques could be widely adopted by practitioners. To illustrate this we describe a preliminary assessment from the South African section of Maputaland that illustrates the value of this process, with a description of the project background, the assessment results and how these outputs have influenced conservation outcomes. We then describe how the five perceptions described above relate to the Maputaland case study and how the analysis could be improved in the future.

The Maputaland Centre of Endemism, which forms part of the Maputaland-Pondoland-Albany hotspot, is an area of *c.* 17,000 km$^2$ that lies in Mozambique, South Africa and Swaziland (Steenkamp *et al.*, 2004). The 9,351 km$^2$ South African section (referred to as Maputaland hereafter) has 28% within reserves (Fig. 1). These are managed by Ezemvelo KwaZulu-Natal Wildlife (EKZNW), the statutory body responsible for conservation in the province of KwaZulu-Natal.

Despite the high level of protected area coverage in the region there is interest in establishing new conservation areas. The agricultural potential of much of Maputaland is generally low and therefore ecotourism and the sustainable use of natural resources have the potential to be the most profitable forms of land use (Goodman *et al.*, 2002). Several private and community initiatives already exist and play an important role in conserving the region's biodiversity (Lindberg *et al.*, 2003) and this sector is likely to expand because of increased national and international support for conservation activities. This means there is a need for a systematic conservation planning exercise that can guide EKZNW and other stakeholders when selecting preferable locations for new conservation-compatible projects outside the state managed reserves. Such a process needs to be based on biodiversity data with a fine spatial scale but most of the available species distribution data have a relatively coarse scale (Lombard, 1995). Therefore, we decided to base this preliminary planning analysis on the distribution of the region's land cover types, as these could be mapped at a relatively low cost from satellite imagery.

## Methods

### Producing the GIS data

A land cover map was produced from two *Landsat 5* satellite images taken in April 1995 and April 1998. The land cover classification was based on an existing system developed for northern Maputaland (Tinley & van Riet, 1981) but modified to reflect more recent work on the region's vegetation communities (Lubbe, 1996; Matthews *et al.*, 1999; Matthews *et al.*, 2001). The final classification system divided Maputaland into five ecological zones (Fig. 1) and contained 29 natural habitat types and five types that have been transformed by agriculture or urbanization. The map was produced using on-screen digitizing and supervised classification techniques. Its accuracy was measured by recording the actual and predicted land cover types at 723 points located throughout the study area; 86.9% of these points were

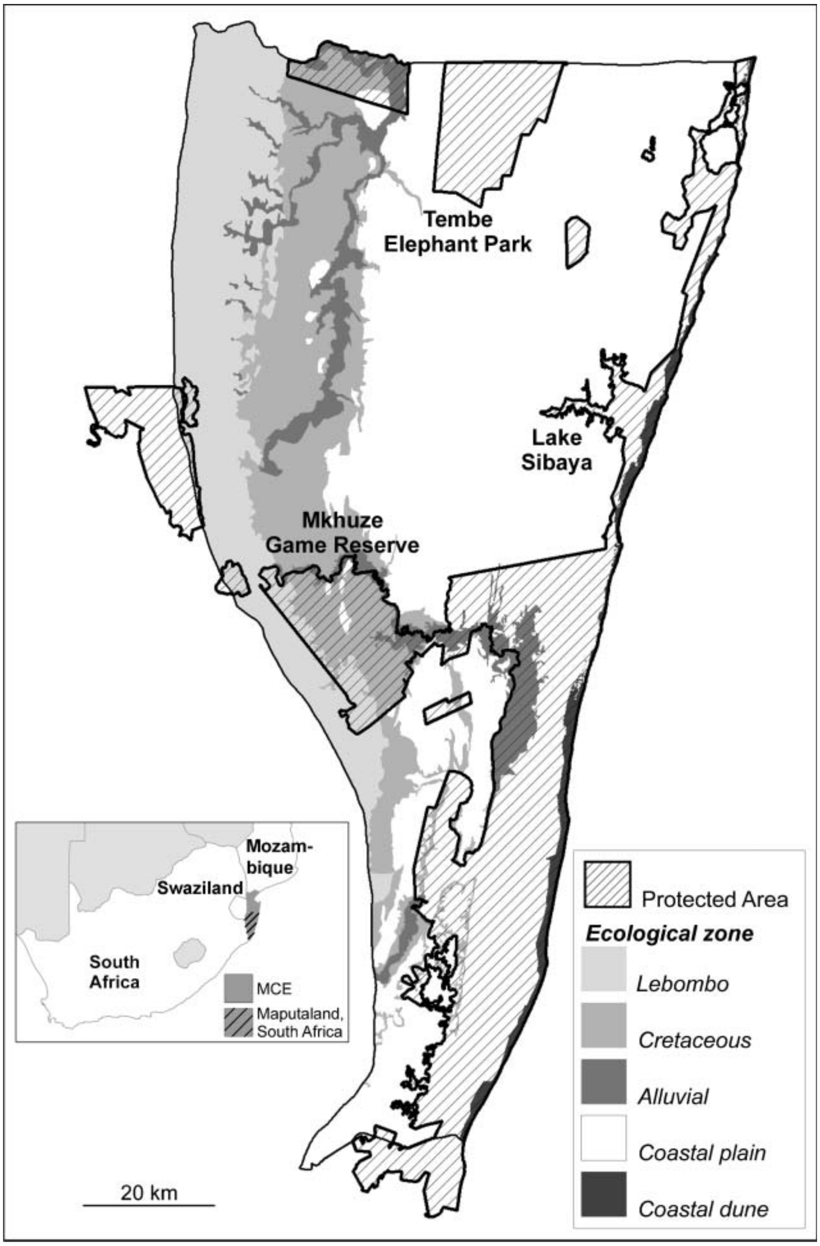


**Fig. 1** The protected areas and ecological zones of Maputaland, South Africa. Inset shows the location of the Maputaland Centre of Endemism (MCE) in southern Africa, in addition to the area of the MCE that occurs in South Africa.

correctly classified (Smith, 2001). The reserve boundaries were digitized from 1:10,000 scale orthophotos. Planning units of 500 * 500 m were used in this analysis, as much of Maputaland consists of tribal land that has not been divided into discrete ownership blocks. These units were produced by using the ET VectorGrid extension in *ArcView 3.2* (ESRI, Redlands, USA) and the area of each land cover type in each planning unit was found by using the Tabulate Areas module in *ArcView*.

### Setting the biodiversity targets

The biodiversity targets were developed during workshops attended by EKZNW staff with experience in conservation planning and the ecology of Maputaland. The group decided that targets should be based on original land cover extent to avoid under representing highly transformed habitats (Pressey *et al.*, 2003) and this was estimated using expert opinion and data on the present transformation levels of each of the ecological zones. It was also decided that land cover types endemic to the Maputaland Centre of Endemism, or that were perceived to be at greater risk of transformation, should have higher conservation targets, and targets were therefore set as being 20% of original extent for most land cover types and 40% of original extent for endemic and threatened land cover types.

### Identifying areas of high conservation value

The data were analysed using *MARXAN*, a conservation planning programme that uses simulated annealing techniques to identify a large number of near-optimal sets of planning units (where each set is called a portfolio) based on an iterative improvement method that incorporates occasional backward steps. Thus, all of the data were first converted to the *MARXAN* format using the *CLUZ ArcView Extension* (Smith, 2004). *MARXAN* measures the effectiveness of a portfolio of planning units by calculating its portfolio cost (Ball & Possingham, 2000), which in this analysis was based on three elements. The first element was the combined planning unit cost, which we set as being the combined area of the planning units, measured in hectares. The second element was the combined target penalty cost, which is the sum of the costs for not meeting individual representation targets. Ideally, these penalty cost values should have practical relevance, allowing *MARXAN* to make trade-offs between the costs of including more planning units in a portfolio and the cost of not meeting a target. In practice, however, such economic data are rarely available. Instead, it is simpler to set target penalties that are much higher than individual planning unit costs, so that *MARXAN* never identifies portfolios that do not meet all of the representation targets. In this case, we set these penalty costs as 100,000 for each land cover type, having checked these were sufficiently high for *MARXAN* to minimize the total portfolio cost by meeting all of the targets. The third element was the total perimeter length of the planning unit portfolio, referred to hereafter as the 'boundary length', multiplied by a boundary length modifier. *MARXAN* minimises this boundary length cost by choosing patches of planning units, rather than a series of isolated units. Increasing the boundary length modifier value favours the identification of portfolios that contain more planning units but are less fragmented. In this analysis we chose a boundary length modifier of 2, based on experimentation to ensure the conservation portfolios were formed of patches that were generally large enough to be ecologically viable.

The simulated annealing process involves running the software a number of times, as it is based on an iterative selection process that generally identifies different portfolios at the end of each run. *MARXAN* then identifies the best of the portfolios it has produced, i.e. the portfolios with the lowest total cost based on summing the planning unit, target penalty and boundary costs. In addition, it produces the summed solution output, which calculates the number of times each planning unit appeared in the different portfolios produced by the different runs. Increasing the number of iterations and the number of runs increases the likelihood of identifying low-cost portfolios but this also increases the amount of computer processing time. As a compromise we set *MARXAN* to identify 200 portfolios by completing 200 runs of $2*10^6$ iterations, which took 19 hours on a Pentium 4 1.6 GHz computer with 512 KB of RAM.

We used 37,943 planning units in the analysis, with each unit having an area of 25 ha. Planning units with more than 50% of their area within existing reserves were set as being already conserved. This was an arbitrary protection threshold but our use of relatively fine-scale planning units reduced the impact of this decision by ensuring most of the units fell entirely within, or entirely outside reserves (Araújo, 2004). In addition, planning units were excluded from any possible conservation portfolio if more than 25% of their area consisted of commercial agriculture, or if more than 80% of their area consisted of subsistence agriculture. These units were excluded because *MARXAN* can select areas based on their connectivity value alone and it was felt these highly transformed units would not be suitable for such a role, with highly transformed commercial agriculture being less suitable than subsistence agriculture. These transformation cut-off points were not based on quantitative data but were chosen to exclude areas of highly fragmented habitats close to the road network. Therefore, it is possible that the 8,013 excluded units could provide connectivity, especially after some habitat restoration.

## Results

The current protection afforded to land cover types by the existing set of reserves ranged from 8.8% for Lebombo grassland to 100% for dune thicket (Table 1). The summed solution map produced by *MARXAN* identified 316 planning units (0.8% of the planning region) that were part of every planning portfolio identified by the 200 runs. All of these irreplaceable units bordered existing reserves and contained 20 different natural land cover types, with *Terminalia* woodland and floodplain grassland being best represented. An additional 3,244 units (8.6% of the planning region) were identified as being part of half or more of the different conservation portfolios (Table 2). Most of these high scoring units were found in areas that were adjacent to existing reserves. However, important patches of coastal plain vegetation were identified to the east of Tembe Elephant Park, to the west of Lake Sibaya and to the south of Mkhuze Game Reserve (Figs 1 & 2).

The total cost of the 200 different portfolios identified by *MARXAN* ranged between 2,608,826 and 3,279,678

**Table 1** Landcover types in Maputaland, South Africa, with the ecological zone in which they occur (Fig. 1), their current conservation status and total area, and their target and conserved areas and percentage of target area conserved (see text for details of targets).

| Landcover type | Ecological zone | Conservation status | Total area (km$^2$) | Target area (km$^2$) | Conserved area (km$^2$) | Percentage of target area conserved |
|---|---|---|---|---|---|---|
| Lebombo aquatic | Lebombo | | 39.6 | 10.4 | 3.9 | 37.5 |
| Rock faces | Lebombo | | 5.6 | 1.5 | 0.9 | 60.0 |
| Lebombo grassland | Lebombo | Threatened | 25.6 | 13.4 | 2.3 | 17.2 |
| Lebombo woodland | Lebombo | | 639.9 | 168.0 | 79.0 | 47.0 |
| Lebombo thicket | Lebombo | | 314.8 | 82.6 | 34.2 | 41.4 |
| Lebombo forest | Lebombo | | 21.4 | 5.6 | 11.4 | 203.6 |
| *Acacia tortilis* woodland | Cretaceous | | 114.9 | 47.6 | 59.6 | 125.2 |
| *Acacia nigrescens* woodland | Cretaceous | | 169.8 | 70.3 | 66.7 | 94.9 |
| *Acacia* bushland | Cretaceous | | 119.2 | 49.4 | 84.0 | 170.0 |
| *Acacia* thicket | Cretaceous | | 210.1 | 87.0 | 41.0 | 47.1 |
| Floodplain grassland | Alluvial | Threatened | 141.7 | 79.0 | 43.5 | 55.1 |
| Reed beds | Alluvial | Threatened | 139.4 | 77.8 | 98.2 | 126.2 |
| Riverine thicket | Alluvial | Threatened | 75.7 | 42.2 | 23.7 | 56.2 |
| Riverine forest | Alluvial | Threatened | 30.7 | 17.1 | 21.7 | 126.9 |
| Sedge swamp | Coastal plain | | 168.3 | 48.8 | 91.2 | 186.9 |
| Hygrophilous grassland | Coastal plain | Threatened | 507.7 | 300.9 | 280.5 | 93.2 |
| Woody grassland | Coastal plain | Endemic | 768.9 | 439.1 | 241.5 | 55.0 |
| *Terminalia* woodland | Coastal plain | | 1,658.7 | 480.8 | 330.9 | 68.8 |
| Woodland on red sands | Coastal plain | | 36.9 | 10.7 | 27.2 | 254.2 |
| Sand thicket | Coastal plain | | 76.3 | 22.1 | 26.1 | 118.1 |
| Sand forest | Coastal plain | Endemic | 144.0 | 83.5 | 73.1 | 87.5 |
| Inland evergreen forest | Coastal plain | Threatened | 153.8 | 89.2 | 117.2 | 131.4 |
| Swamp forest | Coastal plain | Threatened | 31.3 | 18.1 | 24.4 | 134.8 |
| Mangroves | Coastal plain | | 1.4 | 0.4 | 1.4 | 350.0 |
| Beach | Coastal dune | | 51.5 | 11.1 | 47.6 | 428.8 |
| Dune thicket | Coastal dune | | 23.4 | 5.0 | 23.4 | 468.0 |
| Dune forest | Coastal dune | | 112.2 | 24.1 | 111.8 | 463.9 |
| Open water | | | 529.8 | 106.0 | 480.1 | 452.9 |
| Mud | | | 88.5 | 17.7 | 73.3 | 414.1 |

and all of them met the representation targets (i.e. had target penalty costs of 0). These values were calculated by summing the total planning unit and boundary length costs, and the majority of the portfolios had cost values of 2.8–3.1 million (Fig. 3). The four most effective portfolios, which are those with the lowest total portfolio costs, showed strong spatial similarities, although there were some notable differences in the Lebombo zone and east of Tembe Elephant Park (Figs 1 & 4). The most effective portfolio actually had a larger area than the other three and contained more patches, but it had a considerably lower boundary length. All four portfolios included several small patches of planning units that would not act as viable conservation areas, and these patches would therefore need to be expanded, or swapped for similar areas that are adjacent to viable patches, before being used to make final decisions on where new conservation areas should be located.

**Table 2** Conservation value of planning units based on *MARXAN*'s summed solution output (see text for details).

| Conservation value (number of times selected) | Number of planning units | Area (km$^2$) | Percentage of planning region |
|---|---|---|---|
| Highest conservation value (200) | 316 | 79.0 | 0.8 |
| High conservation value (150–199) | 1,220 | 305.0 | 3.2 |
| Medium conservation value (100–149) | 1,708 | 427.0 | 4.5 |
| Low conservation value (1–99) | 9,039 | 2,259.5 | 23.9 |
| Not selected (0) | 6,835 | 1,708.5 | 18.1 |
| Already conserved | 10,812 | 2,665.8 | 28.3 |
| Excluded | 8,013 | 2,003.3 | 21.2 |

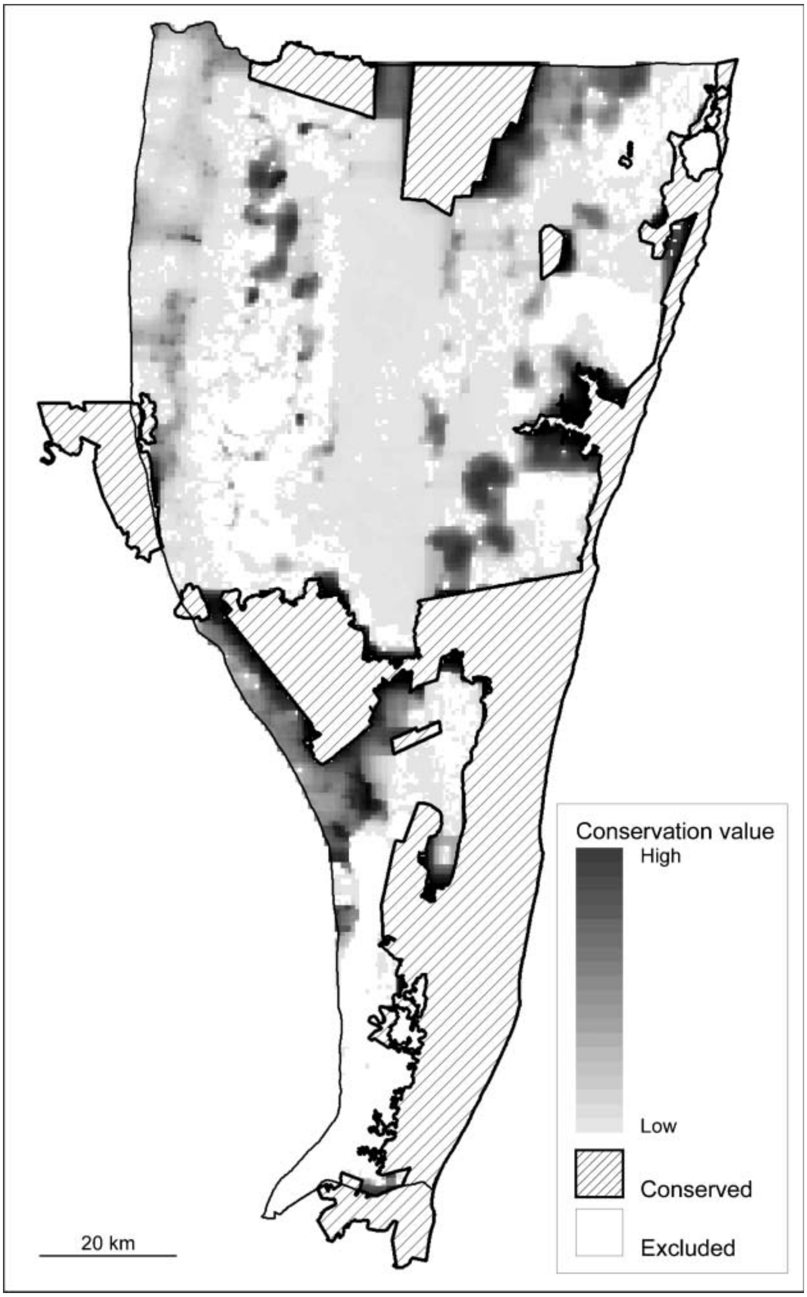


**Fig. 2** Summed solution map showing the number of times each planning unit appeared in the 200 different portfolios identified by *MARXAN*. The map also shows those areas within the existing reserve network and those excluded from the analysis (see text for further details).

## Discussion

The conservation importance of the Maputaland Centre of Endemism is internationally recognized and our analysis is the first to measure the effectiveness of the existing reserve system in the South African section of Maputaland. We have shown that most of the land cover types are well represented, although many of these reserves are ecologically isolated. In addition, this exercise provided valuable data on the location of important conservation areas in the region and this information has already helped inform local land-use decisions. In particular, EKZNW used the summed solution map to identify where new *Eucalyptus* plantations should not be located, illustrating the role of conservation assessments in reducing the risk of losing important biodiversity. Here we discuss how the Maputaland case study relates to the five perceptions described above and the techniques that were used to increase the value of the project outputs for local conservationists. We will also discuss the limitations of this exercise and suggest further work to improve the value of the Maputaland conservation planning system.

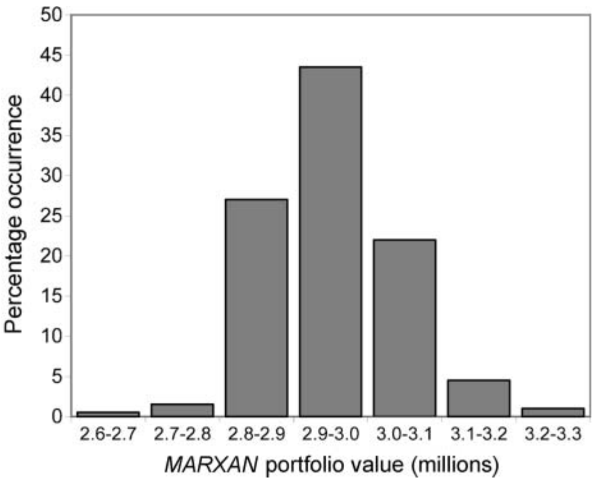


**Fig. 3** Frequency distribution of *MARXAN* portfolio costs, based on planning unit area and exposed boundary length.

### How the five perceptions relate to the Maputaland case study

The Maputaland analysis was based on the *MARXAN* conservation planning software and used *CLUZ*, an *ArcView* GIS extension to manipulate, edit and display the spatial data. This illustrates the inaccuracy of the first perception, as the process was easy to undertake and could be repeated by anyone with the relevant GIS skills. The analysis was based on a 30 m resolution land cover map, which illustrates that the second perception is also false, as the process was not dependent on extensive biodiversity distribution data. However, it is known that distant patches of the same land cover types contain different species assemblages for some groups (van Rensburg *et al.*, 1999), and therefore the analysis may have been improved by setting targets for different biogeographic regions within Maputaland or, ideally, by including data on other conservation features, such as species (Cowling *et al.*, 2004).

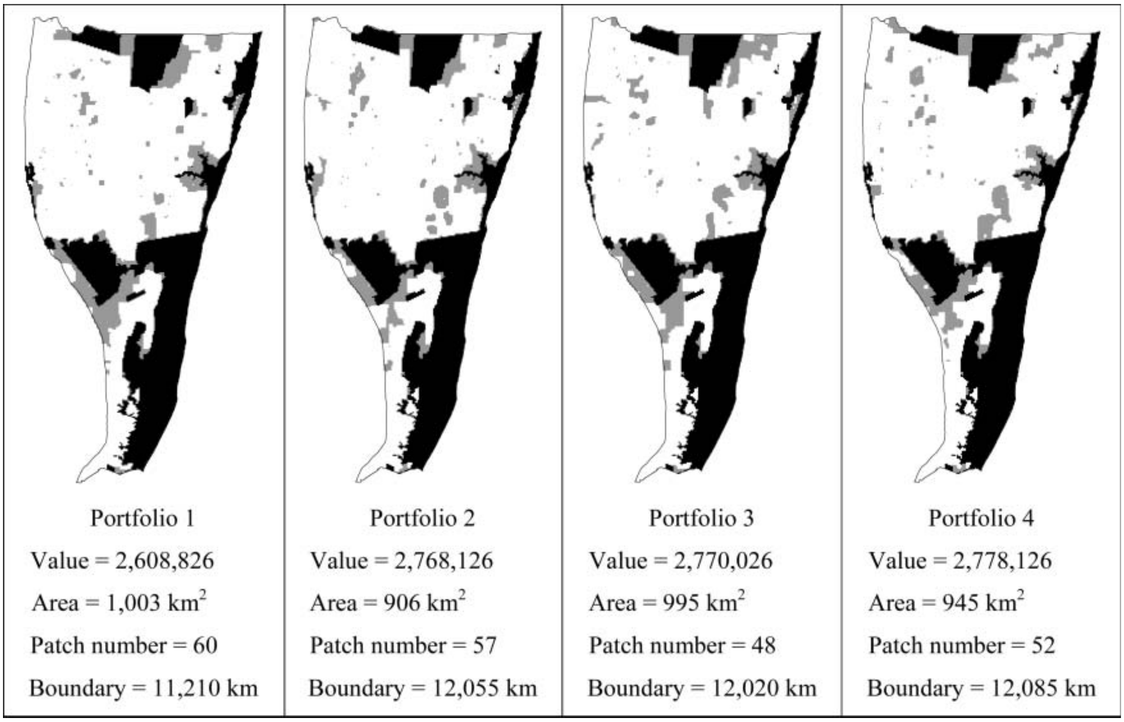
The third perception, of the difficulty in setting representation targets, was also not appropriate to the Maputaland exercise. This was partly because EKZNW ecologists have carried out a similar process in the past (Goodman, 2003) and were therefore used to the process of target setting through expert review. Another key factor was that the results of the exercise were not used to gazette new state-run reserves. This made the representation target setting process less contentious, especially as the final values were similar to data-derived targets that were developed for another important conservation area in South Africa (Desmet & Cowling, 2004).

The fourth perception, of whether the systematic conservation planning process was worth the extra effort, is more difficult to quantify. In financial terms it was based on a land cover map that was derived from satellite imagery costing USD 1,200 in 2005 and that took 6 months to produce. This map was produced as part of a research project (Smith, 2001) but the same work could have been done by one EKZNW technician on a 5-month contract, with one EKZNW ecologist providing support and expertise. The assessment exercise was a much cheaper process and was based on a 2-day workshop to set targets and 2 days to import and analyse the data. This suggests that the same process could be repeated in other locations for similarly low costs, although the systematic conservation planning culture in EKZNW meant that few resources had to be spent on explaining and implementing the results. This may not be the case for less experienced organizations, where resources would be needed to ensure that assessment results were incorporated into land-use planning and policy (Pierce *et al.*, 2005).

The fifth perception, of whether the results identified unsuitable areas, could be particularly pertinent given that the assessment was based entirely on land cover data. However, the effect of this limitation was lessened by choosing the summed solution map as the final output of this process, rather than the best portfolio identified by MARXAN (Ball & Possingham, 2000). This was important for two reasons. Firstly, many of the land cover types are widely distributed throughout their associated ecological zone (Smith, 2001). This provides a great deal of flexibility when choosing a portfolio to meet the representation target and many of these portfolios do so with nearly equal levels of efficiency (Leslie *et al.*, 2003). This meant that *MARXAN* rarely identified identical portfolios and some of these had noticeably different spatial patterns (Fig. 4), which could have led to stakeholders questioning the value of the process. In contrast, the summed solution map was based on the results of 200 runs, and so the results were considerably more robust and repeatable. Secondly, the analysis contained no socioeconomic or political data and so the best portfolio identified by *MARXAN* is likely to contain areas where establishing new conservation areas would be difficult. The summed solution map provided more useful information, as it allows conservationists with local knowledge to identify areas with relatively low scores that can be excluded from future conservation plans because of other constraints. Thus, it was much less prescriptive and reduced the likelihood of producing final assessments that included unsuitable sites.

### Limitations of this case study and future work

This case study from Maputaland has provided valuable information for local conservation planners. However, it



Portfolio 1
Value = 2,608,826
Area = 1,003 km$^2$
Patch number = 60
Boundary = 11,210 km

Portfolio 2
Value = 2,768,126
Area = 906 km$^2$
Patch number = 57
Boundary = 12,055 km

Portfolio 3
Value = 2,770,026
Area = 995 km$^2$
Patch number = 48
Boundary = 12,020 km

Portfolio 4
Value = 2,778,126
Area = 945 km$^2$
Patch number = 52
Boundary = 12,085 km

**Fig. 4** The four most effective portfolios identified by *MARXAN*. Existing reserves are shown in black, and areas recommended for conservation designation are shown in grey.

describes a preliminary analysis that needs to be improved in three ways. Firstly, data should be collected to refine the targets for each of the conservation features. Secondly, data on a wider range of biodiversity elements should be added, including data on species distributions and ecological processes. Thirdly, the system should be supplemented with a range of data to increase the relevance of the planning system and the likelihood that the plans will be implemented. This should include data on risk of habitat loss, to allow implementation to be prioritized (Linkie *et al.*, 2004; Wilson *et al.*, 2005), as well as information on stakeholder support and predicted profitability and opportunity costs for different land use options. Incorporating these biodiversity and implementation data will also reduce the flexibility in the system by increasing the number of targets and constraints, and this will increase the relevance of the best portfolio identified.

This exercise was also important because Maputaland is the focus of a number of conservation initiatives, and our results will help guide this process. This is vital because the priorities of these various initiatives differ, depending on the goals of the associated organizations, and EKZNW needs to ensure that each scheme fits into an overall conservation framework for the region. The Maputaland system described above provides such a framework and will also produce outputs that can be used by other sectors involved in land use planning. Moreover, this system could further increase its relevance by expanding into Mozambique and Swaziland to include the whole Maputaland Centre of Endemism, allowing the development of transnational conservation targets and plans. Such a process is currently being undertaken and involves a major capacity building element so that the governments of all three countries can help conserve the important biodiversity of the region through land use planning.

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## Biographical sketches

Bob Smith has worked in Maputaland on systematic conservation planning projects since 1996. He is the author of *CLUZ*, a GIS-based conservation planning computer programme used by organizations in more than 60 countries worldwide.

Pete Goodman is the coordinator of Biodiversity Research for Ezemvelo KwaZulu-Natal Wildlife and is managing the development of the systematic conservation plan for KwaZulu-Natal. Prior to this he worked for 21 years as the Regional Ecologist for Maputaland.

Wayne Matthews is the regional ecologist for Maputaland for KwaZulu-Natal Wildlife. He is based in Tembe Elephant Park and has been working on the region's vegetation and elephant/vegetation dynamics in Maputaland since 1992.