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Cover photo: A national park is currently being developed along the central Namaqualand coast. This park will conserve the nutrient-rich Benguela marine ecosystem as well as coastal vegetation types. Shown here is short strandveld *with prominent* Didelta carnosa. Photo: Richard M. Cowling.

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Editorial – systematic conservation planning for the real world

R. L. (BOB) PRESSEY

THIS SPECIAL issue of PARKS contains four articles that illustrate the real-world applicability of recent approaches to systematic conservation planning. Some PARKS readers might be sceptical of these approaches. Some might feel that conservation and management problems involve many intangibles, not amenable to analysis by computer, and that finding solutions to these problems depends substantially on the judgement that comes only from long experience on the front line of real-world planning. Others might have encountered some of the scientific literature on the subject and found it too arcane or too removed from day-to-day realities. I hope that this editorial will begin to reassure these readers that today's systematic approaches can help to solve real conservation problems and that they are designed to support, rather than replace, planners and managers. The four articles that follow describe real-world applications of systematic planning in four very different parts of the world – the tropical habitats of Guyana, inland north-western USA, the Mediterranean desert region of western South Africa, and parts of New South Wales.

Although explicit, structured approaches to setting conservation priorities have been applied since the 1970s (e.g. Goldsmith 1975; Ratcliffe 1977), I use the term 'systematic' here to refer to techniques developed since the early 1980s (beginning with Kirkpatrick 1983; and Ackery and Vane-Wright 1984), distinguished by their ability to efficiently identify potential conservation areas that collectively achieve an explicit goal for the region of interest. The early work, and some of the ongoing work, concerns 'reserve selection algorithms', an offputting term for many planners and managers. But the new ideas of the 1980s began a period of research and development, still underway, that has produced some powerful decision-support tools. These have changed the way conservation planning is undertaken in many parts of the world. Systematic approaches share several characteristics:

1. Data-driven. Systematic approaches are typically driven by a matrix of 'features' and 'areas'. The features can be species, vegetation types, or any other natural entities of interest. The areas (referred to variously in the literature as sites, selection units or planning units) are any discrete parts of the landscape that are to be evaluated for their contribution to nature conservation. They can be continuous (e.g. farms, watersheds, or arbitrary grid cells) or discontinuous (e.g. forest fragments, wetlands). The entries in the matrix indicate the occurrence of a feature in an area, in terms of presence or absence, extent, or probability of occurrence.

2. Goal-directed. The areas selected by systematic techniques, or the pattern of optional areas displayed, reflect the explicit goals of the exercise. Most commonly, these consist of quantitative targets for each of the natural features being considered (e.g. at least three occurrences of a species or at least 1200 ha of a vegetation type).

Each feature can have its own specific target. Goals are also framed in terms of suitability for future conservation management, size or connectivity, or areas that must be included or excluded from the analysis.

3. Efficient. A key characteristic of systematic approaches has been their efficiency. They are designed to achieve conservation goals with a minimum of cost, measured by factors such as number or total extent of conservation areas, acquisition cost, or opportunity costs for other uses. The rationale is simple – minimising cost should maximise the chances of achieving the conservation goals. While efficiency continues to be important, recent work (see Cowling, this issue) has recognised that the most effective approaches in some situations are not necessarily the most efficient ones, but the ones that best schedule conservation action in the face of ongoing habitat loss.

4. Explicit, transparent, repeatable. The results of systematic selection analyses can be explained in terms of data, goals and the selection rules, and can be repeated by any number of people. For systematic approaches that serve as a foundation for expert judgements (see all the examples in this special issue), documentation of decisions and their rationale gives transparency, if not complete repeatability. The system being used in New South Wales (see Pressey, this issue) prompts users for the reasons for each decision and logs these for later use so that they are accessible for explanation and reporting. This explicitness is deliberate – it serves as a disincentive for decisions about nature conservation that have more to do with political expediency than the persistence of biodiversity.

5. Flexible. Flexibility comes in two forms. First, it is possible to change the data and goals that determine the outcome of systematic analyses to see how these changes affect the configuration and extent of required conservation areas. This can help to refine the goals of the exercise and to develop and test alternative conservation policies. Second, planning experts can use systematic approaches to change selections, either after an indicative system of conservation areas has been selected (Davis, Stoms and Andelman, this issue) or by using analyses that lay out the options for achieving conservation goals (Richardson and Funk; Cowling; Pressey, this issue).

More detailed information on the development of systematic approaches can be obtained from recent reviews (e.g. Williams *et al.* 1996; Csuti *et al.* 1997; Pressey *et al.* 1997). Much of the work to extend these techniques to form decision-support systems for real-world planning is yet to be described in the literature, but the four articles in this special issue describe some of the current developments.

Systematic approaches inside and outside the ivory tower

During my work in this field, since about 1980, I have had many negative comments about the usefulness of continuing. Most of the comments are unpublished and some are unprintable. Familiar themes are: (1) this work is all very interesting but ultimately a waste of time because important decisions simply aren't made on the basis of data and explicit goals; and (2) the methods are too simplistic to deal with the complexities of the real-world (see also Davis, Stoms and Andelman, this issue, for other concerns expressed about systematic analyses). A couple of people, one from my own organisation, have been moved to write that my research funds should be withdrawn and devoted to biological surveys and land acquisition (e.g. Weatherley 1993;

Pressey's response 1993). I have been asked by a senior government planner when I will stop "fiddling" and do something serious about nature conservation. Interestingly, a similar comment was raised at a major conference in 1991, this time directed at a colleague who works for CSIRO, Australia's national research organisation. He was told before a large audience that he should work for NERO (the acronym for a hypothetical agency called the National Ecological Research Organisation) because he was fiddling while Rome burnt. These criticisms can be amusing for some, if frustrating for those at the receiving end. Significantly though, they miss the point of the work. More significantly, they have been proven wrong.

While scepticism about new ideas is healthy, and there are examples of systematic approaches having been applied naively and counterproductively, planners and managers should be aware of several realities about this field of research and development:

1. Much basic research is needed to fully understand systematic planning tools and to ensure that they work properly, so papers on the finer points of selection algorithms, including academic debates, are necessary to refine the tools. Many planners and managers would have no trouble accepting this argument as it relates to methods for wildlife censusing, assessing the viability of animals with large areal requirements, or predicting the impacts of adjacent agriculture on the edges of reserves. Systematic methods for conservation planning are just as fruitful for solving practical problems, but the connection between the required basic research and the practical solutions is less well accepted.

2. This lack of tolerance for basic research on planning follows, I think, from a common attitude that nature conservation is so urgent that planning is something we should simply get on with, not debate endlessly. This view is only partly correct. We should proceed with the job, using the best means available at the time. But systematic approaches can, and will, continue to improve our ability to protect biodiversity. As in any research field, there is no end to improvement. This is obvious in fields such as medicine and aeronautics, but just as true in conservation planning. Conservation planning will be a redundant line of work when we have made the last decision about priority for allocating conservation resources, but that is a long time off.

3. Perhaps the most compelling argument for the sceptics to consider is that systematic approaches not only work in the real world but can improve the way that planners and managers make decisions. They have changed our thinking about global conservation priorities (Bibby *et al.* 1992; Olson and Dinerstein 1998); they have shaped important conservation policy (e.g. the National Forest Policy Statement in Australia); they have made conservation decisions credible and defensible in the face of opposition; and they have improved the quality of decisions that can be made by experienced conservation planners. These last two points are enlarged below and then illustrated in the four case studies that make up this special issue.

The importance of systematic approaches

The importance of systematic approaches is perhaps best argued by looking at the consequence of not being systematic. The term *ad hoc* is used here to refer to decisions that lack proper perspectives on conservation priorities in a region (the 'favourite places' problem) or are intended simply to increase the number of reserved hectares regardless of regional priorities. *Ad hoc* decisions about new conservation areas can be made with the best of intentions or can be cynical. Either way, they are a long-standing and pervasive problem. Throughout the world, a familiar pattern has emerged – reserves are concentrated in landscapes that are least valuable for extractive uses, easiest to protect, least charismatic, and least in need of protection (Runte 1979; Strom 1979; Adam 1992; Beardsley and Stoms 1993; Aiken 1994; Rebelo 1997; Barnard *et al.* 1998). This is despite the overwhelming importance of *in situ* conservation for the persistence of biodiversity and the major role that protected areas have to play here.

So what can systematic approaches do about this? Several things. They can:

- Encourage planners to be explicit about what they are trying to achieve.
- Provide a picture of conservation values in a regional context that can alert planners to the importance of areas they had not previously considered.
- Show clearly the implications of using particular data sets and particular goals.
- Illustrate the effects of making some areas mandatory for conservation and excluding others from contention.
- Allow rapid investigation of alternative policy scenarios.
- Allow transparent, structured, negotiated planning between interest groups, including local communities with strong interests in the outcomes.

So far, so good. But all the possibilities listed above can still be overwhelmed by expedient political or bureaucratic decisions. There are no known algorithms for eliminating political pragmatism, but systematic approaches can reduce the negative effects of conservation cynicism by:

- Influencing policy at a high level (e.g. the influence of the 1992 National Forest Policy Statement on the conservation outcomes in eastern New South Wales in 1996 – Pressey 1998).
- Promoting the accountability of decision-makers by reviewing the contribution of proposed new reserves to the conservation of regional biodiversity (e.g. Wright *et al.* 1994) or providing criteria for reviews of decisions after they have been made (e.g. McKenzie *et al.* 1996).

None of this should be taken to mean that systematic approaches must be, by definition, 'right'. Like any other field of science, systematic conservation planning is evolving. There continues to be healthy debate amongst its practitioners, and much of the work involves testing and comparing alternative ideas. But this testing ensures that the analyses, when applied in the knowledge of their limitations, are reliable. Further, the explicitness of the analyses means that the results can be understood and questioned.

This editorial is also not intended to suggest that systematic approaches necessarily produce better results for nature conservation than a group of experts working with maps and pens. But I have seen systematic analyses enlighten regional experts by highlighting the importance of areas that they had not previously considered. More importantly, as data sets become larger and planning goals more complex, computers rapidly become much better than humans at handling the required analyses consistently and effectively. Systematic approaches in these cases are tools in the hands of expert planners, not mindless replacements for people who understand the region.

Where to from here?

'Reserve selection' algorithms and the decision-support tools that evolved from them are now being adapted and applied for off-reserve conservation in several places. The requirements for locating and designing protection measures other than reservation are not fundamentally different – the main question to be addressed is how to allocate limited conservation resources (in space and time) to achieve explicit goals. Another recent movement of systematic analyses has been from terrestrial environments, where the techniques were developed, into estuarine and marine areas. Again, the fundamental issues for planning are the same, even if the natural processes and methods of implementation differ.

There is potential for the current work on systematic planning to develop in many directions. Four challenges raised by the articles in this issue are:

1. Moving from methods that efficiently represent or sample biodiversity in actual or notional protected areas to methods that schedule conservation action to minimise the extent to which regional goals are compromised by ongoing loss of habitat.
2. Constructing alternative future landscapes for study regions so that the implications of different policies or approaches to systematic planning can be better understood.
3. Developing methods that can integrate planning both for biodiversity pattern (e.g. species localities, maps of vegetation types) and for natural processes (e.g. migration, patch dynamics, adjustment to climate change, speciation).
4. Further adaptation of decision-support tools to facilitate their use by community groups and other stakeholders, including methods for balancing conservation and economic factors.

The techniques that come from this work will continue to improve the ability of planners and managers to maximise the persistence of biodiversity.

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An approach to designing a systematic protected area system in Guyana

KAREN S. RICHARDSON AND VICKI A. FUNK

Guyana is a small country on the northern coast of South America. It presents a unique opportunity to establish a representative system of protected areas to conserve its enormous diversity of habitats and species. Guyana has a small population concentrated on the coast and has only recently opened its natural resources to exploitation, so most of its environments are intact. This article describes an approach to designing a protected area system in Guyana based on patterns of species distribution. Little was known about the distribution of biodiversity prior to a study conducted in 1995. The biodiversity patterns known from that study, and reported here, are based on many person-years of collecting and consolidating data from collections. As well as outlining an analytical approach, the article discusses the real-world constraints on establishing protected areas. Other aspects of this study are still underway and include comparisons of different surrogates of biodiversity as a basis for conservation planning, analysis of different threats to biodiversity, and assessments of conservation priorities at different spatial scales.

GUYANA IS a country of 215,000 km^2 on the northern coast of South America. It is the only country on the continent that does not have a protected area system, despite its wealth of biodiversity and tropical forests. Although small in size, Guyana has diverse ecosystems, from the Pakarima mountains in the west, to the white sand forests over the Guyana Shield and the Amazonian rainforests and savannas of the south, much of which remains undisturbed. Guyana's other comparative advantage is that is has a relatively small population (800,000 people), concentrated predominantly along the coast. The primarily intact forests and savannas and the absence of agricultural and urban pressures on the land allow for a unique opportunity to conserve the patterns and processes of biodiversity in a systematic fashion.

From the 1970s to the early 1990s, Guyana remained a closed county to most foreign scientists and researchers. Its forests were virtually self-protected due to the lack of trade. That all changed in the early 1990s after democratic elections. Guyana was starved of foreign exchange and was ready to exploit its vast tropical forests and its deposits of gold and diamonds. Facing international pressure to harvest its forests and exploit its minerals in an environmentally-friendly fashion, the Government of Guyana agreed to take the first steps in establishing a system of protected areas that would encompass areas representative of the major ecosystems of the country. The challenge before the Government was to design a system that would protect valuable biodiversity while respecting Amerindian rights and land use and, at the same time, allow economic development.

Presently, Guyana only has one national park, Kaieteur Falls, located in the scenic area where the Potaro River drops off the escarpment of the Roraima formation to the valley about 270 m below. Officially the park, established in 1974, is 11 hectares in size and covers just the area around the waterfall.

Threats to biodiversity

Although the effects of human land use on biodiversity in Guyana predate European colonisation, they have been most pronounced in the past eight years. Several species of Guyanese timber, in particular greenheart (*Chlorocardium rodiei*), have been selectively exploited for over 200 years (Williams 1997), but exploitation has intensified since the arrival of foreign investors in the early 1990s. State forests in Guyana – forests that can be given out for timber concessions – presently cover approximately 8.8 million ha of the 14 million ha of exploitable forests (Parry and Eden 1997). Of the existing State Forest, approximately 8.2 million ha is currently under concession, although only one third of this has been actually logged (Parry and Eden 1997). A moratorium was placed on the granting of new concessions as a condition of foreign aid but this has recently been lifted and the State Forest is now being extended by approximately 1 million ha towards the Rupununi savannas in the south of the country (Parry and Eden 1997). The largest forestry concession, Barama, covers 1.6 million ha and is controlled by a consortium of South Korean and Malaysian investors licensed to cut wood for the plywood and raw timber markets (Williams 1997). Forestry concessions are now the primary threat to biodiversity in Guyana. Many of the existing concessions are increasing the volume of wood cut each year to maintain profits and this is putting a lot of pressure on Guyana's forests (Parry and Eden 1997).

Waterfall at Kaieteur National Park. Photo: Karen Richardson.

Mining also dates back several hundred years in Guyana but the emphasis has shifted recently from bauxite to gold and diamonds. Mining for gold and diamonds is concentrated in the hilly sand and clay regions, primarily in the riverbeds. There is one large-scale mine, Omai, located near the middle of the country. This mine suffered a serious problem in August 1995 when the dam of a tailing pond collapsed and dumped 3 million m^3 of cyanide-contaminated water into the river system (William 1997). This was a serious accident, but its long-term impact cannot yet be measured. The majority of mining is small-scale riverbed extraction that is very detrimental to the condition of river systems and to species in freshwater and riparian habitats. An overall assessment of small-scale operations is difficult since there are tens of thousands of them across the country. Further major impacts from mining are likely if large-scale exploration and mining operations in the south are allowed to proceed.

Other land uses that are a threat to biodiversity in neighbouring countries include agriculture, urban sprawl and ranching. Although these occur in Guyana, they have a small impact on biodiversity at present. Agriculture is primarily carried out along the coast, where over 80% of the population lives, and poses little threat to the biodiversity found in the interior of the country. Cattle ranches, which are widespread across the southern savannas, have a limited impact due to the low density of cattle (Anon. 1994).

Moves toward establishing new protected areas

The ability of the Government of Guyana to regulate and monitor environmental degradation and protection has improved over the years. In 1997 an Environmental Protection Agency was created to oversee and monitor environmental activities. Guyana is also a signatory to the Convention on Biological Diversity and has made a commitment to environmental protection and the conservation of natural resources in a National Environmental Action Plan (NEAP), ratified by Parliament in 1994. However, the Government has also clearly stated that a major reason for creating a national system of protected areas is to improve its access to international markets for the sale of timber, gold and diamonds. These markets are becoming limited unless countries can demonstrate sustainable use of their natural resources (Williams 1997).

Since the mid-1970s, scientists and conservationists have proposed that various areas in Guyana be protected. Despite the efforts of international agencies, conservation organisations and research institutions to assist with the protection of these areas, little has been done on the ground. Several expansions of the tiny Kaieteur Falls National Park have been proposed and the Government continues to consider a draft bill that would enlarge the park. However, the Government, with the assistance of the Commonwealth Secretariat and the Global Environment Facility (GEF), has set aside 360,000 ha as part of the Iwokarama Rainforest Programme to demonstrate sustainable forestry and biodiversity protection.

Central forests of Guyana.
Photo:
Karen Richardson.

In 1994, the Government of Guyana requested the assistance of the GEF, through the World Bank, to help it establish a national protected area system. The project proposed by the Government for funding to the GEF required a systematic, country-wide approach to be taken to identify and protect areas supporting biodiversity of global and national significance. During the preparation for the project, some of the initial steps towards planning a national system were taken:

- Data were compiled from as many existing specimen collections as possible.
- Stakeholders and parties previously and presently involved in protecting biodiversity in Guyana, from indigenous

peoples to international non-government organisations (NGOs) and research organisations, were invited to participate.

- Preliminary modelling and analyses were carried out.

The larger project, to be funded by several donors including the GEF, will help establish an institutional, regulatory and legal framework for managing protected areas in Guyana as well as providing funds for the management of two key areas in the system. Money from the GEF is also being budgeted to create a sinking fund to assist with the gradual implementation of management for other areas.

Gradual implementation of the system is necessary due to both funding restrictions and the country's nascent institutional arrangements and capacity to manage protected areas. The choice of the first two areas in the national system has not yet been made and will only be finalised after the scientific, social, economical and political factors have been weighed carefully. The following section summarises an approach to selecting priority conservation areas based on irreplaceability values (as defined by Pressey *et al.* 1993) and vulnerability to loss of biodiversity.

Approach to designing a national system of protected areas

Available data on biodiversity

Prior to the study carried out by the Smithsonian Institution, the only available biologically-based map was a vegetation map produced from LANDSAT TM images taken between 1990–1995 (Huber *et al.* 1995).

In cooperation with the Smithsonian Institution, a database on point localities for many plant and animal species was established (see Funk *et al.* 1999 for details). The Smithsonian has worked in Guyana on and off for over 50 years and already had a large database of geo-referenced specimens. The database was complemented with data from all the institutions with substantial holdings of specimens from Guyana. Ten taxonomic groups of plants and animals were selected for analysis: birds, mammals, herps, Chrysobalanancea (large understorey trees), ferns, Lecthyidaceae (Brazilian nut tree family), legumes, melastomes, orchids, and sedges. Data on termites and butterflies, although available, were not included due to small sample sizes. The ten groups were chosen on the basis that: (a) a specialist was available for consultation; (b) they occurred in many vegetation types; and (c) at least one taxon was restricted and at least one taxon was widespread (Funk *et al.* 1999).

One important feature of this database is that it is all specimen based – no observational data are included. All data were verified and, if a geocode was missing, it was assigned using either a computerised gazetteer of known localities in Guyana or using 1:100,000 topographical maps (Funk *et al.* 1999). Approximately 30 % of the data collected were eliminated due to the lack of precise geocodes. In total, 16,500 records were used comprising 312 species, 122 genera and 88 families. Although the south-east part of Guyana is believed to be very rich, access to the area is restricted due to a border dispute with Suriname and, with the exception of two mammal collecting expeditions, no one has brought out specimens from this region. Because of the lack of data, it was decided not to include this part of Guyana in the work reported here.

As expected in a country with very few roads, collection localities are clustered mostly around airstrips and along rivers. To reduce this sampling bias, data were modelled to obtain both actual and predicted (with a 95% confidence level) distributions of species. Modelling analyses were done with DOMAIN, a program that predicts species distribution based on presence-only data and a point-to-point similarity metric (Carpenter *et al.* 1993). Predictive variables were elevation (from a 30 second resolution digital model), mean annual temperature, surface geology, vegetation type, and the precipitation of the driest month (October). These variables were mapped onto a grid of 1 km². Only species with ten or more location points were modelled, which further reduced the original dataset and also potentially biased the data against rare species.

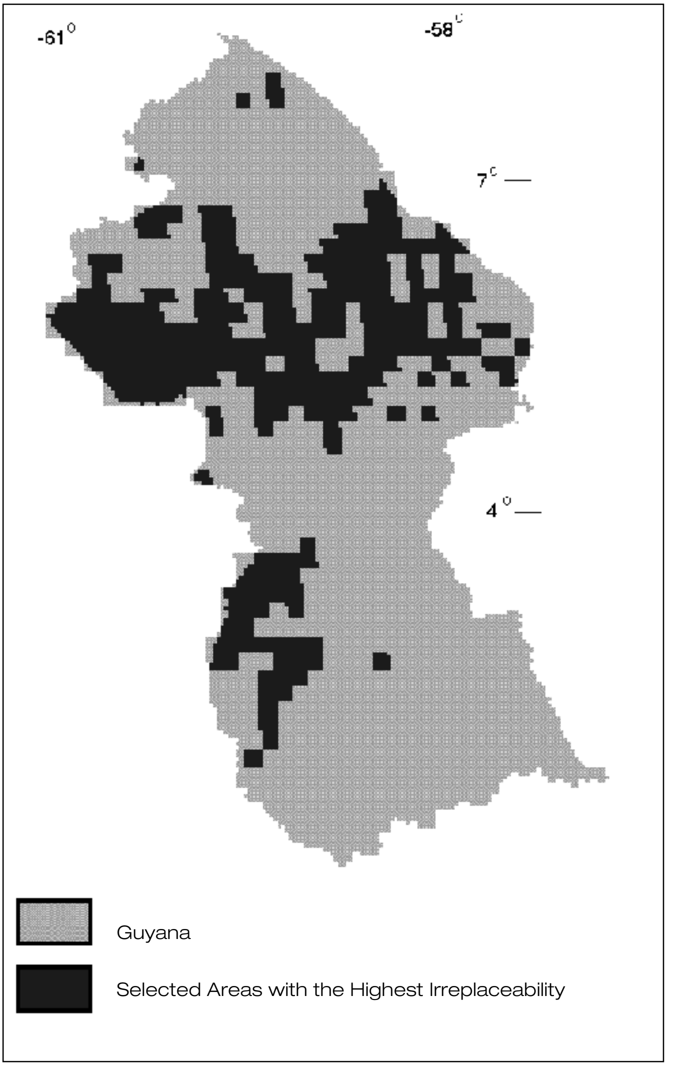

Figure 1. *Map of Guyana showing areas of high irreplaceability value.*

Using the data to identify conservation priorities

C-Plan, a conservation-planning tool developed by the New South Wales National Parks and Wildlife Service (see Pressey, this issue), was used to map irreplaceability values across Guyana on a 16 km² grid. The conservation target can be modified in C-Plan from 0%–100% representation for each species. In this case, a uniform target of 15% of predicted distribution was applied to all species. This target was chosen for demonstration purposes only.

In the first instance, the irreplaceability value, defined as the potential contribution of a site to the achievement of a conservation goal (Pressey *et al.* 1993), was calculated for each of the 941 grid cells irrespective of any possible threat. A map of areas with the highest and second highest irreplaceability values combined across Guyana is shown in Figure 1. The areas with highest irreplaceability are located primarily in the central tall, evergreen, non-flooded forests, the Pakarima mountains, the southern Rupununi savannas, the area around Kaieteur Falls, and the Kanuku Mountains. High values for these sites are not surprising, as they represent unique areas with distinctive species compositions. The areas selected with the highest irreplaceability also represent the key ecosystems well (Table 1). Some of these areas, however, are not threatened by land use and so need little or no immediate intervention to conserve the biodiversity found within them, at least in the short-term. The high

Table 1. Representation (%) of key ecosystems: (a) in areas with high irreplaceability (HIrr); and (b) when State Forests are excluded from the analyses (SFEx).

Key ecosystem	(a) HIrr	(b) SFEx
Tall, evergreen non-flooded forest (rain forest)	92	12
Tall, evergreen flooded riparian forest (Mora forests)	61	31
Tall/medium evergreen lower montane sclerophyllous forest	44	14
Tall/medium basimontane forest	44	30
Lowland shrub savanna (Rupunnuni)	37	11
Tall, evergreen sclerophyllous forest (Wallaba forest)	35	9
Tepui Forests	18	0
Scrubland	17	12
Low, semi-deciduous, seasonal forest	16	12
Arborescent swamp	16	1
Tall evergreen seasonal forest	15	29
Tall, evergreen hill and forest	15	60
Low evergreen seasonally flooded swamp forest	14	0
Lowland savanna on white sand	14	4
Medium evergreen montane forest	14	11
Tall/medium evergreen lower montane forest	12	7
Medium/low estuarine mangrove forest	12	2
Cultivated fields and secondary forests	11	44

Tepui forests of the Pakarima, for example, are quite inaccessible. On the other hand the Kanuku Mountains have recently come under threat from oil exploration and the proposed extension of the State Forest. Likewise, parts of the Rupununi savannas are under consideration for gold exploration.

To address the vulnerability of areas with high irreplaceability for biodiversity conservation, data were collected, in conjunction with Conservation International, on the locations of towns, state forests, forestry concessions, mining concessions and Amerindian lands. For the purposes of this paper, a simplified vulnerability index was calculated as the proximity of a grid cell to an existing forestry concession, although other threatening processes will be included as further analyses are developed. The vulnerability index varied from 0–1 to reflect the distance of a grid cell from a forestry concession (a value of 1 indicates the cell is within a forestry concession, a value of zero indicates maximum distance – 24 cells – from a concession). These values were then mapped (Figure 2). This vulnerability index map and the irreplaceability value map were overlaid using Idrisi 2.0 (Clark University 1997) to produce a map of areas with both high vulnerability to logging and high irreplaceability (Figure 3). The majority of areas are in the central, tall evergreen, non-flooded forest located in the middle of the State Forest, but some highly irreplaceable and slightly vulnerable areas also occur around Kaieteur Falls, the Pakarima and the Kanuku mountains.

Implementation of a national protected area system

Presently, the Government of Guyana has agreed to consider two areas as the foundation of the National Protected Areas System (NPAS). One of these areas will most likely be an expanded area around Kaieteur Falls to include the main watersheds. The Government has already drafted a bill to expand Kaieteur to

580 km². Although this would certainly be better than the present 11 ha, the analysis in this paper shows that it would still not protect all of the irreplaceable biodiversity in the area. Another more pressing problem is that any further expansion of the proposed Kaieteur area would have to include land held by Amerindians. Initial discussions with the leaders of the Amerindian village near Kaieteur Falls were promising but, more recently, Amerindian leaders across Guyana have requested that the selection of areas for a national system of protected areas be put on hold until outstanding land rights issues with the Government are resolved. Unfortunately, there has been no hold placed on granting forestry concessions, so the situation for conserving biodiversity values before they are compromised is becoming critical. Furthermore, the land rights issue will affect logging only marginally – Amerindians have title to only a small percent of land in Guyana, mostly on the outskirts of dense forest.

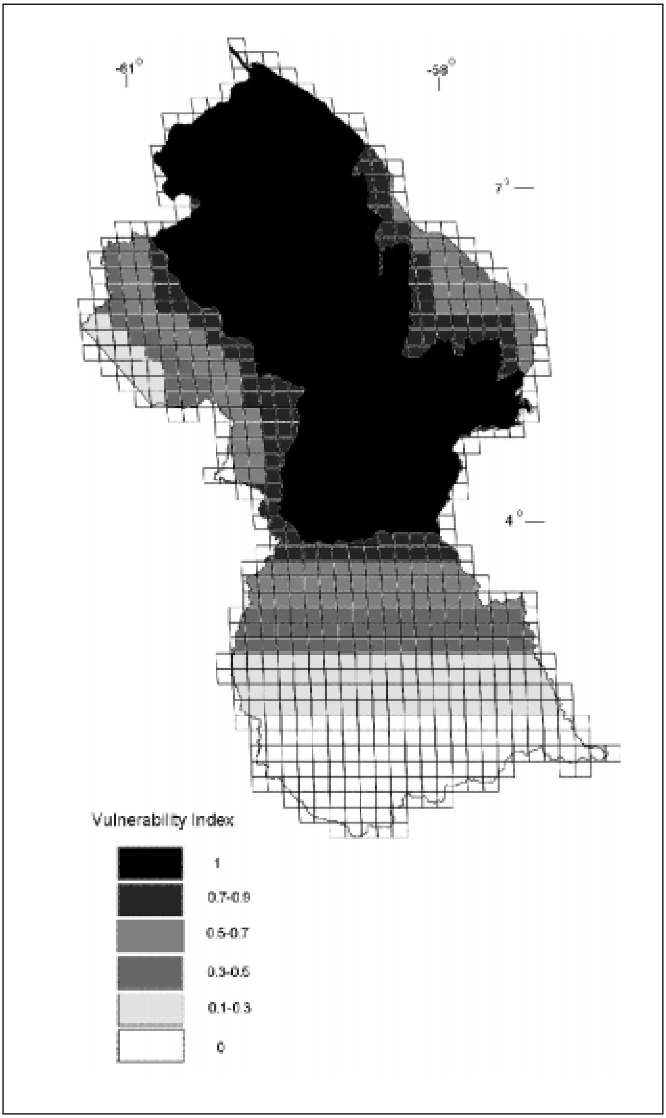

Figure 2. Map of Guyuna showing vulnerability values based on proximity to forestry concessions.

The selection of an area that is both highly vulnerable and highly irreplaceable within the State Forest would be desirable as the second of the two initial protected areas. Several possibilities are shown in Figure 3. Likewise, areas in the mora (*Mora excelsa*) and wallaba (*Eperua* spp.) would be desirable for the same reasons. Since a large portion of the land within concessions has only been selectively logged or not yet logged, it is still possible to protect a large, viable area within existing logging concessions. The various forestry laws and acts in Guyana allow for land to be excised from a concession for the purpose of conservation, although this has not yet been done. If none of the land within the State Forest was made available for conservation in the national system of protected areas, Guyana would fail to meet its own goal of representing its major ecosystems. Figure 4 shows that if the State Forests were excluded from protection, every other grid cell in Guyana would have to be protected to even begin to reach the goal of 15% representation of biodiversity. The areas with the highest irreplaceability values cover most of the country. Moreover, even if this were done, the Government would still fail to adequately conserve a large number of its major ecosystems (Table 1, column b).

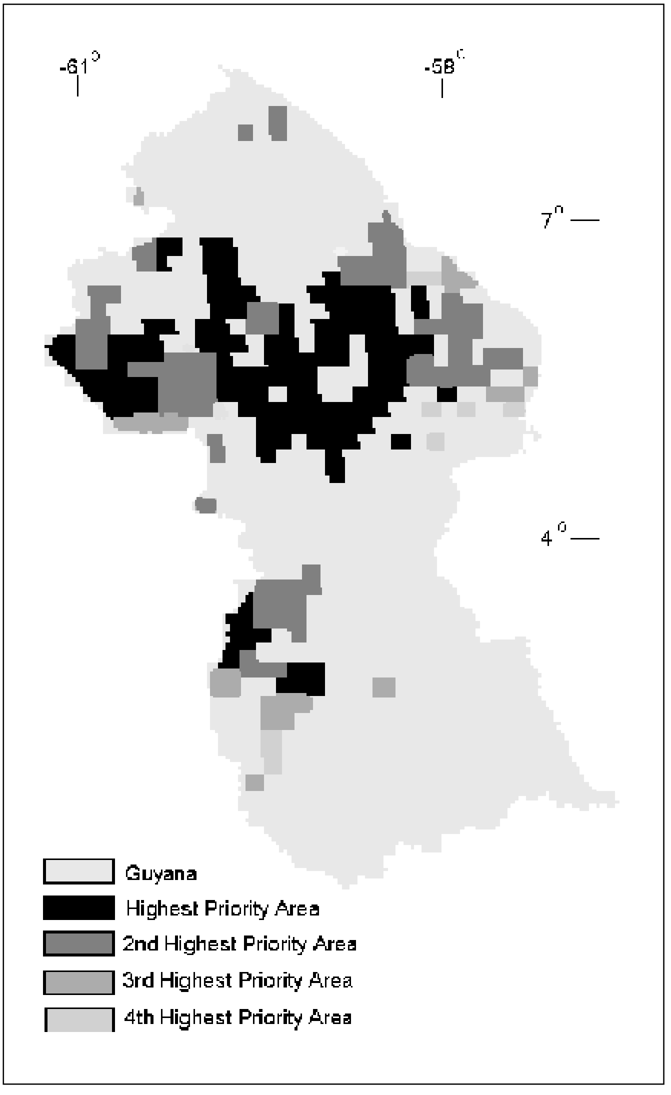

Figure 3. *Map of Guyana showing areas of high irreplaceability and high vulnerability.*

If the areas shown in Figure 3 could be protected as a system, the system would still fall short of protecting all the major ecosystems in Guyana, but it would protect the areas most vulnerable to logging. Other ecosystems that would remain under-represented in such a system but which are not under as much threat, such as riparian forests and savannas, would have to be protected over time and according to available funds in order to complete the system.

Currently, the new Government of Guyana has stalled on plans to implement a system of protected areas. The reason does not seem to be lack of data or planning tools. Indeed, the results of scenarios based on irreplaceability and vulnerability, such as the one presented in this article, have been discussed with the Government. Rather, the hesitation to gazette land for protection appears to be based on the policies of a new Government, elected in 1997, which wants to consider all the options for each parcel of land in terms of forestry and mining concessions before locking up areas to protect biodiversity. This process of consideration could be very lengthy because complete resource assessments are not available in Guyana. It is also contrary to the approach initially adopted by the Government in 1994 when it requested funding from external donors to help set up protected areas. Nevertheless, the process of negotiating with the Government, using scenarios developed by systematic planning approaches, will continue as new data become available and new policies are formulated. This will allow the implications for Guyana's biodiversity of decisions about resource extraction to be fully understood. Recently, at the launch of an environmental educational campaign designed by Conservation International, aimed at increasing awareness about protected areas, the Government of Guyana made another plea for the international community to assist it with the establishment of a protected area. The interest of the government of Guyana to protect its biodiversity is still paramount. As plans are being discussed by the GEF, German Government and European Union, to provide funding for a protected area system, are still under discussion, the Smithsonian Institution continues to assist with the biological collections at the Centre for Biological Diversity, University of Guyana.

Conclusion

The long-term persistence of biodiversity in Guyana depends on a system of protected areas that will capture not only examples of the various ecosystems but biodiversity that is both irreplaceable and vulnerable to various threatening processes throughout the country. The present capacity of Guyana to implement management plans for more than two or three areas is limited. As that capacity grows, Guyana will be able to add areas to the system. The key to making the system work from the beginning is to map out, in an explicit, transparent way, which areas would form its core and which areas can be negotiated and traded for other areas. Using irreplaceability and vulnerability to map priority conservation areas in Guyana allows for a whole system plan to be proposed but also modified over time. New and arising issues such as Amerindian land rights and future mineral exploration will have to be factored in as part of the vulnerability index to keep the selection of areas as realistic as possible. Similarly, patterns of irreplaceability will change to some extent as new data are incorporated into the planning process. The great advantage of this approach to system planning is its transparency and flexibility in the light of the complicated and changing land uses in Guyana as the country grapples with sustainable economic development.

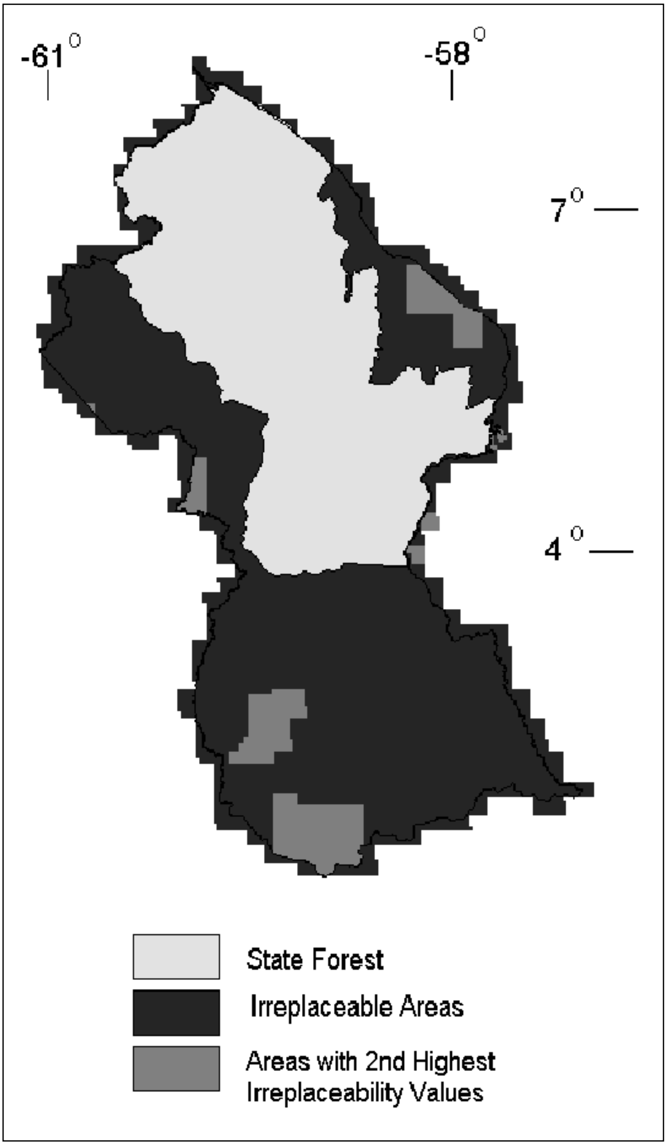

Figure 4. *Map of Guyana showing irreplaceability values if State Forests are excluded from protection.*

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Planning for persistence – systematic reserve design in southern Africa's Succulent Karoo desert

RICHARD M. COWLING

This article discusses a new approach to systematic conservation planning that avoids some of the limitations of previous work in the field. Much of the development of methods for conservation planning has focused on the representation of biodiversity pattern (e.g. species records, vegetation types) in reserves. It has also generally assumed that the implementation of all proposed new reserves will be rapid, so that it is not necessary to consider which proposed areas should be the first to receive actual protection on the ground. This assumption can be far-removed from the real world where implementation of a reserve system is mostly gradual and where ongoing biodiversity loss during the process of implementation can compromise the attainment of representation goals. A strategy is needed that locates and designs new reserves to promote the conservation of natural processes, as well as biodiversity pattern, and that guides the scheduling of conservation action in the face of limited resources. This article includes a conceptual framework and a protocol for designing a reserve system that explicitly considers both natural pattern and process. Just as importantly, the approach described assumes gradual implementation of new reserves, which calls for timely interventions to ensure the retention of irreplaceable patterns and processes that are highly vulnerable to threats. The study region is southern Africa's Succulent Karoo biome, an internationally recognised desert hot-spot, characterised by exceptional diversity and rarity of plant species. The study described here is not theoretical – it will identify the highest conservation priorities in the region and guide the allocation of available funds to those areas.

FOR THOSE of us involved with the development and management of reserves, the inevitable and deeply challenging question is: how much of the original complement of biodiversity will this reserve system protect in 50, 100 or 1,000 years time? We can be sure that between now and some not-too-distant date, a reserve and its surrounds will be subject to a great deal of change: climate change will have influenced all aspects of ecosystem structure and function inside the reserve and, under the influence of a growing human population, the unconserved matrix outside the reserve will have been almost entirely transformed. How do we design reserves so that they can protect unique complements of species and habitats, as well as absorb the impacts of change within and outside their boundaries and so allow the persistence of species and habitats far into the future? This is not an easy task.

The unusually reliable winter rainfall over much of the Succulent Karoo ensures good displays of spring flowers almost every year. At Skilpad Wildflower Reserve in the Namaqualand Rocky Hills bioregion, this garish monoculture of Ursinea cakelifolia *on an old field attracts tens of thousands of tourists each year.* Photo: R.M. Cowling.

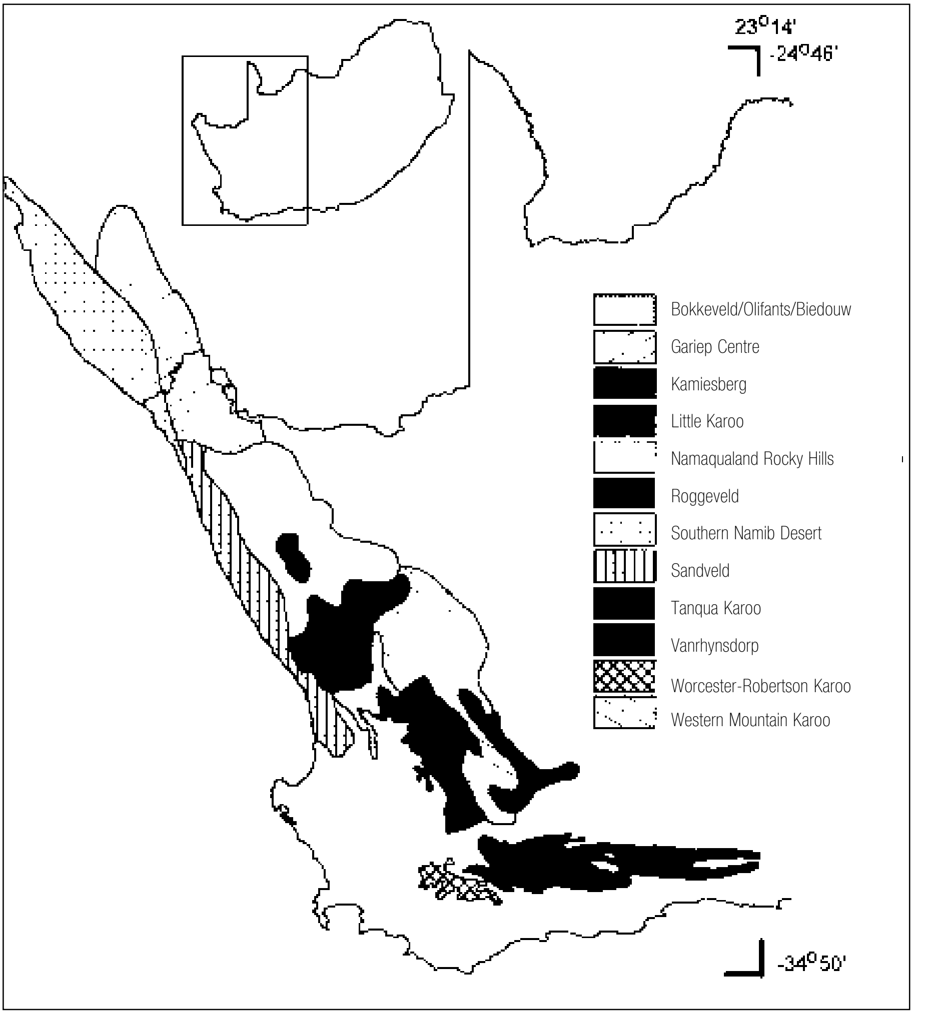

Figure 1. *Map of the Succulent Karoo showing the delimitation of bioregions.*

This article presents a protocol for designing a reserve system intended for the long-term conservation of biodiversity. In order to do this, consideration must be given not only to the conservation of biodiversity patterns, but also to the processes that sustain these (Cowling *et al.* 1999). Designing for persistence may incur a short-term cost for the representation of biodiversity pattern. Ultimately, however, this approach should maximise the persistence of biodiversity in the landscape.

The setting

The study region for this exercise is the Succulent Karoo biome, a predominantly winter-rainfall desert region that occupies 112,000 km^2 on the arid fringes of South Africa's Cape Floristic Region (Figure 1). On account of its spectacular biodiversity, this region is the only arid land to qualify as a global biological hot-spot (Cowling and Pierce 1999). It includes 4,849 species of vascular plants (40% endemic) and is home to the richest succulent flora in the world. It is also a centre of diversity for reptiles and many different groups of invertebrates. The recent and explosive diversification in the Mesembryanthemaceae, the largest succulent plant family in the region, has been described as an event unrivaled among flowering plants (Desmet *et al.* 1998).

As a consequence of an unusual composition and high endemism, the flora of the Succulent Karoo is unique (Cowling and Hilton-Taylor 1999). The region includes 1,940 endemic plant species and 67 endemic genera. Local and regional plant richness is very high. Thus, on average 70 species are recorded in a ten-hectare plot (in one plot, the tally was 113!) (Cowling *et al.* 1998). Larger areas support about four times the number of species than comparable winter-rainfall deserts elsewhere in the world. This high regional richness is the result of high compositional change of species-rich communities along environmental and geographical gradients, i.e. high beta and gamma diversity, respectively (Cowling and Hilton-Taylor 1999). Many species are extreme habitat (mainly edaphic) specialists of limited size range. Point endemism is most pronounced among succulents (especially Mesembryanthemaceae) and bulbous lineages, and is concentrated on hard substrata, especially quartzites, shale ridges and quartz lag-gravel plains (Schmiedel and Jürgens 1999). The area is home to 851 Red Data Book species, 46% of which have ranges that occupy less than one quarter degree square (or 68,000 ha) (Lombard *et al.* 1999).

The current situation

Given its global significance as a biodiversity hot-spot (Cowling and Pierce 1999), and its long-standing recognition as a regional conservation priority (Hilton-Taylor 1994, Rebelo 1994), the current protected area system in the Succulent Karoo is woefully inadequate. Only 2.1% or 2,352 km^2 of the Succulent Karoo is conserved in six statutory reserves (Hilton-Taylor 1994). Larger reserves (>10,000 ha) occur in only four of the Succulent Karoo's 12 bioregions and conserve only 80 (9%) of its 851 Red Data Book plant species (Lombard *et al.* 1999).

More than 90% of the Succulent Karoo is used as natural grazing (Hilton-Taylor 1994), a form of land use that is, at least in theory, not incompatible with the maintenance of biodiversity and ecosystem processes. About 100,000 km^2 remains in a natural or semi-natural state. However, much of this remaining natural habitat is vulnerable to a wide range of immediate threats (Cowling *et al.* 1999). These, in order of their overall importance, are:

- The expansion of communally-owned land and the associated overgrazing and desertification.
- Overgrazing of commercial (privately-owned) rangelands.
- Agriculture, especially in the valleys of perennial rivers.
- Mining for diamonds, heavy minerals, gypsum, limestone, marble, monazite, kaolin, ilmenite and titanium in the Sandveld, Southern Namib Desert, Vanrhynsdorp Centre and Richtersveld bioregions.
- Illegal collection of succulents and bulbs.

Bearing in mind the overall conservation value of the Succulent Karoo, the looming threats to its biodiversity, and the potential availability of large tracts of land for reservation, a systematic approach to the conservation of the region is long overdue. This article provides a framework for designing and implementing a reserve system, based on contemporary concepts and techniques in systematic conservation planning.

A conceptual framework for conservation planning

The past 20 years have witnessed a shift in conservation planning from *ad hoc* reserve establishment to systematic protocols that identify whole sets of complementary areas which collectively achieve some overall conservation goal – the 'minimum set' approach (Pressey *et al.* 1993). In this strategy, the conservation goal consists of quantitative targets for each species (e.g. at least one occurrence) or each habitat (e.g. at least 10% of its total area). The aim is to represent the required amount of each species or habitat in as small an area as possible. Usually, rapid implementation of the reserve system is assumed implicitly (Figure 2), so there is no basis for deciding how to schedule conservation action in relation to prevailing threats.

A more realistic scenario, however, is for implementation of the reserve system to take years or decades, during which time the agents of biodiversity loss continue to operate. In such situations, strategies for maximising representation on paper must be complemented or replaced by those that maximise 'retention' in the face of ongoing loss or degradation of habitat (Figure 2). A crucial consideration in maximising retention is the assignment of priorities based on the irreplaceability or conservation value of a site, and its vulnerability to biodiversity loss as a result of current or impending threatening processes (Pressey *et al.* 1996; Pressey 1997). Areas of high irreplaceability and high vulnerability are the highest priorities for conservation action. This approach should minimise the extent to which representation targets are compromised by ongoing loss of habitat and species.

A further step is needed, however, for conservation planning to truly address the long-term persistence of biodiversity. The implementation of reserve systems that are designed to achieve only the representation of biodiversity pattern will not ensure long-term conservation. This is because these systems do not explicitly consider the ecological and evolutionary processes that maintain and generate biodiversity (Cowling *et al.* 1999). The ultimate goal of conservation planning should be the design of systems that enable biodiversity to persist in the face of natural and human-induced change. Design is defined here as the size, shape, connectivity, orientation and juxtaposition of conservation areas intended to address issues such as viable populations, minimisation of edge effects, maintenance of disturbance regimes and movement patterns, continuation of evolutionary processes, and resilience to climate change.

Figure 2. *Four strategies for conservation planning as framed by conservation goals (pattern vs. pattern + process) and implementation constraints (rapid vs. gradual). Note that the only path from retention to retention + persistence is by adding design to representation.*

Implementation constraints

Conservation goals	RAPID	GRADUAL
PATTERN	Representation	Retention of pattern
PATTERN + PROCESS	Representation + design (+ **persistence**)	Retention of pattern + process (+ **persistence**)

Given that the implementation of reserve systems is almost always gradual, and accompanied by ongoing loss of habitat, the conservation of both pattern and process will require consideration of:

- Representation and design in the identification of potential conservation areas.
- Sound decisions about the progressive implementation of conservation action so that land use and other threats have minimal impact on the desired outcome.

Conservation planning is therefore about promoting both retention and persistence (Figure 2). Importantly, the only path from retention to retention + persistence is by adding design to representation (Figure 2) before identifying priorities for implementation. In the implementation phase of a reserve system designed for retention + persistence, the importance of threatening processes in compromising the achievement of both representation and design goals will need to be considered and balanced (Cowling *et al.* 1999). This strategy should achieve greater long-term benefits for biodiversity than alternative strategies based only on the representation of pattern.

In the next sections of this article, the need to shift conservation strategies from representation to retention + persistence (Figure 2), is illustrated by describing three alternative strategies for conservation planning in the Succulent Karoo. The third strategy – designing for persistence – is the current focus of conservation planning in the region.

Representation of pattern

Here the aim is to set conservation targets for biodiversity pattern in terms of numbers of localities or areas of habitat. The approach in the Succulent Karoo has been to focus on the region's extraordinarily rich Red Data Book (RDB) flora, comprising 851 species and subspecies, most of which are rare and highly restricted in distribution (Lombard *et al.* 1999). There are four reasons why this approach has been used:

- Existing maps of land types are too crude to represent the fine-scale habitat patterns typical of the Succulent Karoo (Cowling *et al.* 1999).
- Since the RDB flora shows very high compositional turnover along environmental and geographical gradients, a conservation system based on representation of RDB species is likely to capture a great deal of floristic diversity generally (Lombard *et al.* 1999).
- Components of the RDB classification embody threatening processes – so planning for these species promotes the retention of pattern in the face of threats.
- The RDB database comprises 1,972 distribution records captured at the quarter degree scale (QDS = 15' x 15'), and is considered to be reasonably reliable as a presence-absence database.

Setting a target of conserving each RDB species at least once, a standard reserve-selection algorithm identified 127 QDS in the Succulent Karoo (58% of the all QDS in the region) as a minimum set for reservation (Lombard *et al.* 1999). This very large number of potential conservation areas reflects the highly localised distribution patterns (i.e. high local endemism) of the RDB flora. If the seven currently reserved QDS are used as starting points for the analysis, then the same algorithm requires a further 122 QDS (129 in total) to conserve all remaining species. The existing reserves thus do not contribute much towards the goal of conserving all species (they contain only 80 species, or 9% of the RDB flora), whereas the top seven QDS selected by the algorithm, ignoring existing reserves, contain 314 species (or 37 % of the RDB flora).

No existing reserve occurs in a QDS containing more than five QDS endemics, there being nine QDS with more than five species confined to a single QDS. These results indicate the costs, in terms of representing pattern, of *ad hoc* reservation in the Succulent Karoo. Despite the inadequacies of the existing reserves in representing the plant species considered here, they are either national parks or provincial reserves and their deproclamation is unlikely.

Clearly, it will be impossible to include populations of all Succulent Karoo RDB species in a formal reserve system. Therefore, there is a need to identify priorities for the implementation of reserves. One way of doing this is to select the highest ranking areas from the analysis just described – for example, the top 5% of QDS. These 11 core QDS plus the seven QDS with existing reserves contain 440 RDB species (52% of the total) in just 8% of the Succulent Karoo (Lombard *et al.* 1999).

Retention of pattern

A refinement of the prioritisation above is to consider the need for retention of species in the face of ongoing threats. Owing to limited funds, the expansion of the formal reserve system in the Succulent Karoo will take time. This constraint requires a strategy that maximises the retention of pattern (or minimises habitat loss and extinction) by scheduling the allocation of limited conservation resources to those areas with high scores for both irreplaceability and vulnerability (Pressey *et al.* 1996, Pressey 1997).

Lombard *et al.* (1999) identified priorities for retention based on the endemicity of RDB species (based on the number of QDS they occupied – a measure of irreplaceability) and their vulnerability (using a seven-scale scoring system where extinct species were scored highest, and non-threatened species lowest). A threat value for each species was calculated by adding that species' endemicity and vulnerability values. Threat values for a QDS were calculated as the sum of threat values for all species in that QDS.

Figure 3 shows the 122 QDS identified by the minimum set analysis in the previous section prioritised according to threats (Lombard *et al.* 1999). These results attempt to combine the strategy of representation (represent all species in the reserve system) with the strategy of retention (proclaim reserves in the most threatened areas first to minimise the extent to which the representation goal will be pre-empted by loss or degradation of habitat). For retention, the top 5% of QDS, representing the core for an expanded reserve system, together with the seven QDS with existing reserves, contain 426 RDB species (50% of total) in 8% of the Succulent Karoo. Notably, this priority set of areas contains fewer species than the analysis only for representation, above. However, scheduling conservation efforts in this way will achieve more biodiversity conservation on the ground, if not on paper.

Designing for persistence

Conserving areas with high concentrations of threatened species will fulfill retention goals in the short term but will not buffer the long-term negative impacts on biodiversity from changes in climate and land use outside reserves. Several steps, shown in Table 1 and summarised below, are required to identify and implement a reserve system designed for the persistence of biodiversity (Cowling *et al.* 1999). The crucial issue here is the retention of both pattern and process (Figure 2).

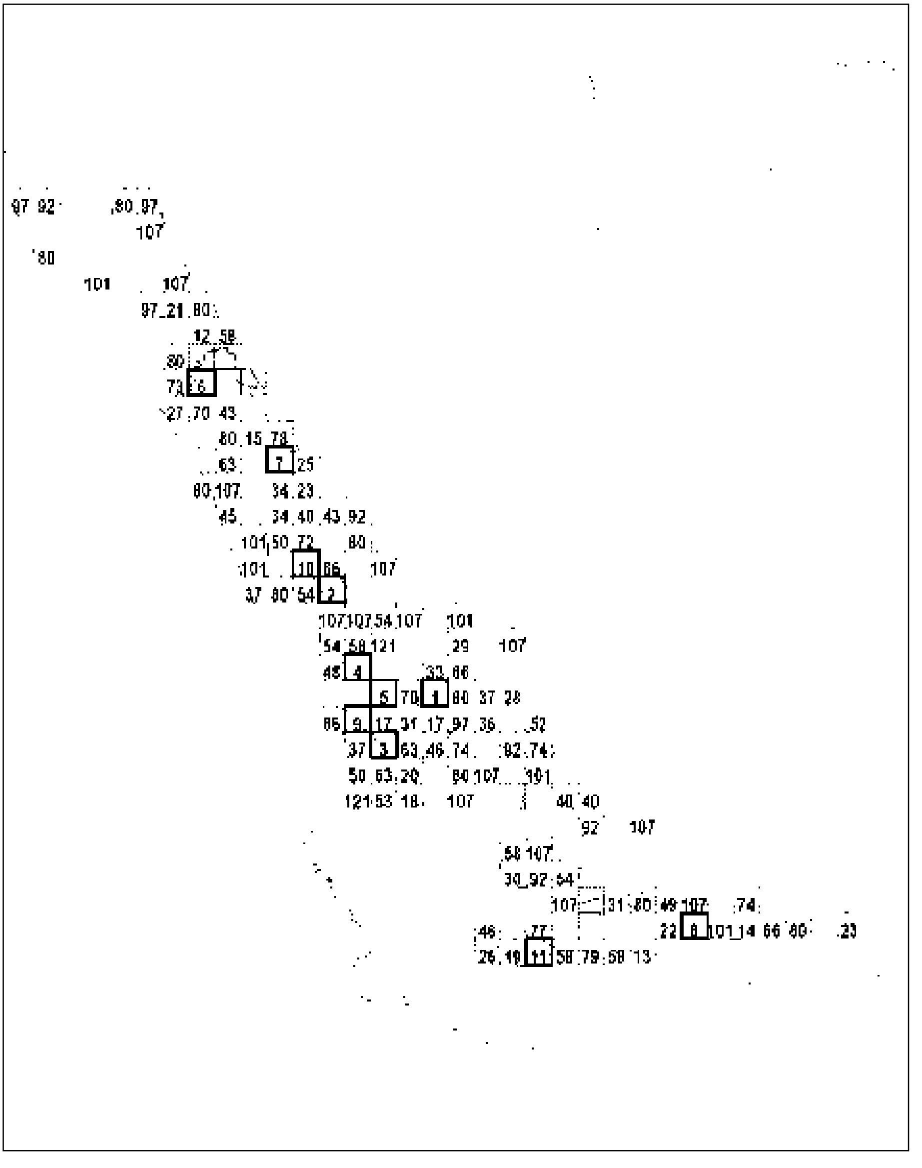

Figure 3. *Reserve configuration identified by Lombard* et al. *(1999) to represent all 851 Red Data Book species in the Succulent Karoo in at least one quarter-degree square (QDS). Numbers (1–122) are threat prioritisation values (see text) recognising the existing reserved QDS (shaded). This prioritisation is intended to maximise retention in the face of ongoing threatening processes. The top 11 QDS, mooted as core conservation areas, have bold borders.*

Table 1. *Steps in the protocol for achieving retention + persistence.*

Step 1	Identify types, patterns and rates of threatening processes.
Step 2	Identify natural features to be protected. These will be elements of biodiversity pattern, e.g. species, habitats, as well as spatial components of the region that act as surrogates for ecological and evolutionary processes (see Table 2 for examples).
Step 3	Set targets for representation and design.
Step 4	Lay out options for achieving representation + design targets.
Step 5	Locate and design potential conservation areas to achieve representation + design targets.
Step 6	Implement conservation actions in priority order.

The first step is to identify types, patterns and rates of threatening processes. In the Succulent Karoo, this amounts to identifying cadastral units (i.e. farms and blocks of state land, communal land and land owned by mining companies) as well as particular habitats and natural processes, and then assessing their vulnerability to threats such as grazing, agriculture, mining and climate change (Cowling *et al.* 1999). Furthermore, the time-frame over which these threats will operate must be estimated.

The second step involves identification of the spatial components that need to be protected in the expanded conservation system. Some of these will be elements of biodiversity pattern. Others will serve as surrogates for the ecological and evolutionary processes that should be protected in a reserve system intended for retention + persistence. The type and size of spatial components, together with their role in conservation in the Succulent Karoo, are outlined in Table 2. The geographical location of some these components is shown in Figure 4. Cowling *et al.* (1999) provide additional information on the role of these processes in maintaining biodiversity in the region.

In the third step, quantitative targets must be set for the representation of these spatial components, taking into account the need of each component for protection from threatening processes. This presents a serious challenge to conservation planners. For example, how many and which quartz-field drainage basins are required to maintain diversification of Mesembryanthemaceae lineages? Which climatic gradients and associated juxtaposed landscapes are most likely to facilitate migration of poorly-dispersed organisms in response to climate change?

Argyroderma pearsonii (Mesembryanthemaceae) is one of the numerous minute succulents endemic to the quartz fields of the Vanrhynsdorp bioregion. Photo: R.M. Cowling.

The fourth step requires that the options for achieving representation + design targets (Figure 2) – the ultimate but elusive goal for conservation planning – are laid out. A way of mapping the spatial options for achieving a set of conservation targets is to calculate and map the irreplaceability of each part of the landscape (Pressey *et al.* 1995). A map of irreplaceability, with values allocated to all parts of the landscape, is therefore a map of the options for achieving a set of targets. Areas that are totally irreplaceable are non-negotiable parts of an expanded conservation system, regardless of what form of conservation management is applied (see Step 6). Other areas are replaceable and negotiable to varying extents.

Step 5 is to locate and design potential conservation areas for representation + design. The overall aim of this step is to identify conservation areas that will collectively achieve all the targets for pattern and process. The system of proposed conservation areas might be much larger than the area considered feasible, but sound decisions about the relative importance and urgency of protection for specific parts of the landscape (Step 6) can only be made when the full requirements of all targets have been laid out. Candidate areas will be chosen that contribute to as many targets as possible.

Table 2. Spatial components of a system of conservation areas in the Succulent Karoo intended for retention + persistence (Figure 2).

spatial components	size (ha)	role in conservation
Small conservation areas	< 1,000	Protection of viable populations of locally endemic plant species and plant-insect interactions; maintenance of small-scale disturbance regimes.
Large conservation areas	> 100,000	Protection of viable populations of large mammals including gemsbok, leopard and black rhinoceros and nomadic birds; maintenance of faunal metapopulations associated with small-scale disturbance patches.
Entire sand movement corridors	10,000 – 50,000	Maintenance of inland movement of sands and gradients of soil development important for soil-specific plant assemblages and promoting diversification of plant species.
Whole river catchments draining from the uplands to the coast	15,000 – 40,000	Protection of riverine and wash habitats that: have distinctive species assemblages; provide stepping stones of hard substrata for movement; and associated diversification, of plant species between the uplands and the coast; contain nesting sites for ecologically important hymenopteran pollinators; and provide dry-season refugia for larger ungulates.
Juxtaposed edaphically different habitats	1,000 – 5,000	Maintenance of ecological (edaphic) diversification of poorly-dispersed lineages.
Whole minor drainage basins associated with quartz fields	1,000 – 10,000	Maintenance of presumed evolutionary fronts, distinct between basins, consisting of different nested clades of derived taxa.
Areas spanning the gradient from uplands to coastal lowlands and interior basins	50,000 – 1,000,000	Maintenance of seasonal migration of springbok and other ungulates and the associated disturbance regimes.
Large and steep climatic gradients	5,000 – 3,000,000	Facilitation of shifts in species' distributions in response to climate change.

Step 6 is the actual implementation of conservation action – a very complex part of the planning process. It involves three interdependent lines of work, which are likely to proceed in parallel, not sequentially. These are:

- Scheduling conservation action (reservation or other) for specific parts of the region.
- Deciding on the balance between strict reservation and off-reserve management.
- Fine-tuning of conservation recommendations by selective inspection of areas on the ground and reassessment of data.

Scheduling requires that the recommended timing of conservation action should minimise the extent to which conservation targets are compromised before conservation management is applied (Pressey 1997; Lombard *et al.* 1999). This requires information on both threat (the likelihood or imminence of adverse impacts – from Step 1) and irreplaceability (the consequences of loss or degradation of habitat – from Steps 4 and 5). When conservation goals deal with both pattern and process, as is the case here, there are no established ways of comparing the risks of alternative approaches to implementation. For example, how should the outright loss of five RDB species or a 20% loss of the target for a land type be compared to the effect of a new mine

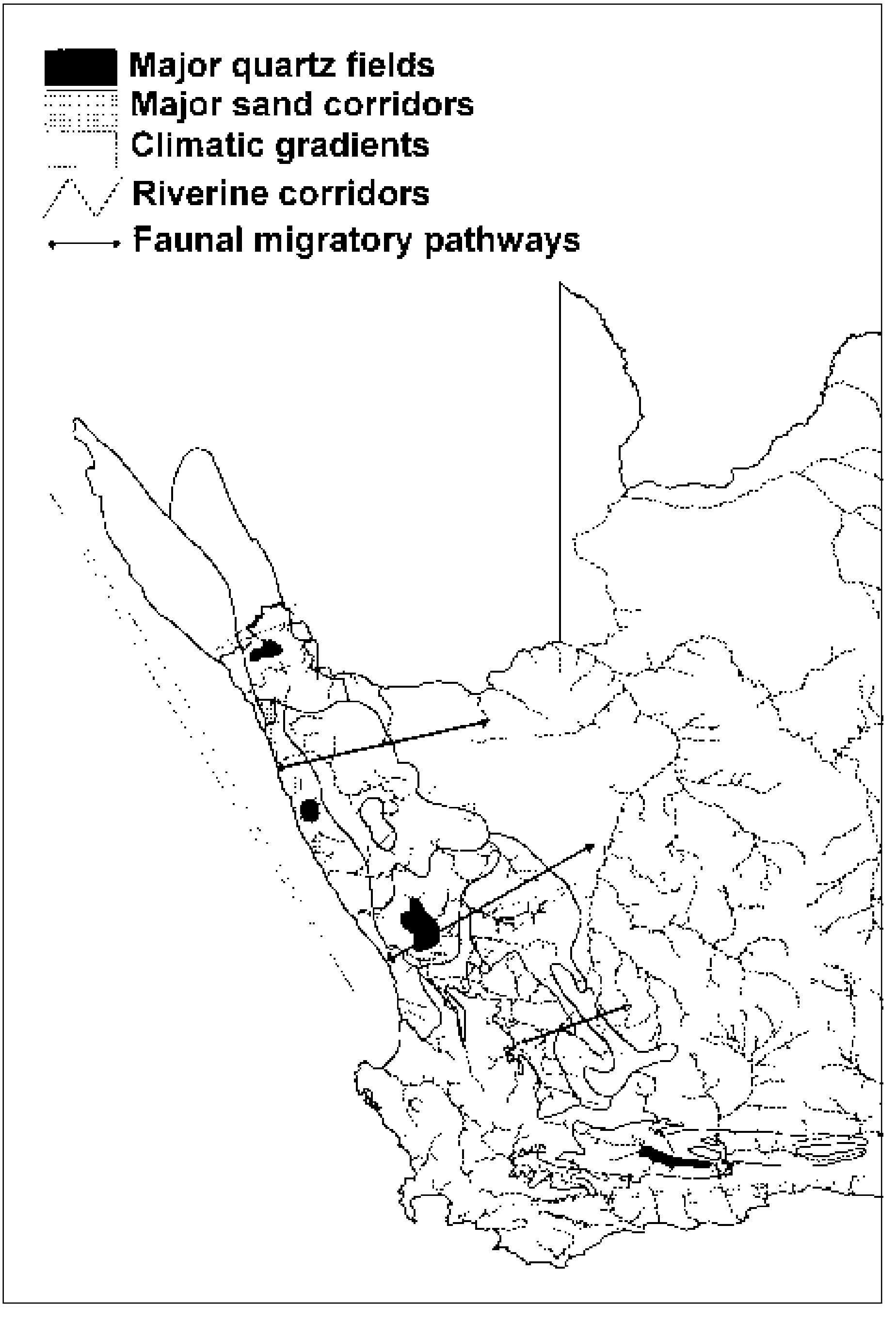

Figure 4. Location of spatial components in the Succulent Karoo required for representation in a system of conservation areas designed for retention + persistence (see Figure 2 and Table 2). Thickness of lines indicating climatic gradients is proportional to the steepness of the gradient. In some cases (e.g. sand movement corridors, riverine corridors), spatial configuration is pre-defined by the features themselves; others (e.g. faunal migratory pathways, climatic gradients for migration or adjustment to climate change) do not have pre-defined boundaries.

covering 100 ha of a sand corridor, or the narrowing of a migratory pathway for ungulates?

The issue of which form of protective management should be applied to particular parts of the landscape is complex. Decisions about the form of management to be applied to specific areas will depend on:

- The need to use off-reserve management as a fall-back when resources for strict reservation are limited or when reservation priorities are unavailable for acquisition.
- The distribution of threatening processes that do not warrant protection by reservation.
- Which parts of the unreserved matrix most require management to maintain the integrity and connectivity of reserves.

All these decisions must be taken in the context of the variety of off-reserve management tools currently or potentially available.

It is likely that a system of conservation areas designed for retention + persistence will be achieved at a cost in terms of short-term representation of pattern. This cost comes mainly from the need to conserve large areas of uniform habitat in order to maintain key processes. For example, Cowling *et al.* (1999) designed an indicative system of three large reserves, each covering between 250,000 and 350,000 ha and collectively comprising 11 QDS, which fulfilled representation targets for all of the spatial components presented in Table 2. When compared to Lombard *et al.*'s (1999) equal-sized system identified for the retention of biodiversity pattern (Figure 3), the former system conserved 37% fewer RDB species. This cost in terms of representation should be offset by the benefits of developing a reserve system in which natural pattern and processes are likely to persist in the face of change, and which will be implemented so that threatening processes have minimal impact on conservation targets.

What to do in the Succulent Karoo?

South African National Parks (SANP) has committed itself to implementing a reserve system for the Succulent Karoo, subject to budgetary constraints. The adopted strategy is to design for retention + persistence around the nodes of core areas identified by Lombard *et al.* (1999). Work on a reserve in the Vanrhynsdorp Centre, using the protocol described above, is far advanced. At this scale, individual farms and other cadastral units, rather than QDS, will be used as the units of planning and management. Targets will be set for the representation of fine-scale vegetation types as well as other spatial components, particularly quartz-field drainage basins, that support unique ecological and evolutionary processes (Desmet *et al.* 1998; Schmiedel and Jürgens 1999). Owing to the fact that most land is privately-owned, state land is subject to land claims, and much of the area is vulnerable to mining, negotiations with stakeholders must be inclusive and will be complex. Detailed planning will also be undertaken in the Hardeveld-Kamiesberg node identified by Lombard *et al.* (1999).

The Richtersveld National Park comprises a harsh desert mountain landscape. However, this 1,620 km² park, which has average annual rainfall of about 70 mm, harbours some 500 species of plant, including at least 50 endemics. Photo: R.M. Cowling.

In addition to leaf succulents, many Succulent Karoo endemics are bulbs. Here Oxalis ecklonìana *shelters behind the sun-harvesting winter foliage of* Boophone haemanthoides. Photo: R.M. Cowling.

There are four major gaps in knowledge that constrain the approach to systematic conservation planning recommended in this article. These are:

- Insufficiently detailed habitat maps for the Succulent Karoo.
- Inadequate spatio-temporal assessment of threats to biodiversity.
- Insufficient appreciation of the areal requirements and landscape surrogates of ecological and evolutionary processes.
- Lack of a protocol for comparing the conservation value (or irreplaceability) of pattern versus process.

While the first two points are not particularly challenging to address, the others are problems of great conceptual and intellectual depth. Planning must proceed before these problems are resolved, but improvements in understanding such issues will be made in the coming years and will be fed into the ongoing process of conservation in the region.

It will never be possible to include all of the Succulent Karoo's enormous biodiversity within a system of formally protected reserves. At present there are sufficient funds over the next five to ten years to increase the conservation estate by about 500,000 ha or 4.5% of the region. Both the location and scheduling of these new conservation areas must be carefully judged.

However, of equal importance is the management of biodiversity in the intervening matrix, especially for the maintenance of key processes that require large tracts of land (Table 2). Of great relevance are biodiversity-friendly farming practices. A good example – indeed, a role model – exists within the top priority QDS identified in Lombard *et al.*'s (1999) retention analysis (Figure 3). This area in the Western Mountain Karoo bioregion comprises a matrix of agricultural lands and small remnants of natural habitat that support a staggering number of locally endemic plants, chiefly showy and charismatic geophytes. A large ecotourism industry has developed around the spring flower season and increasing numbers of farmers are retaining and managing remnants in order to benefit from this. Given that populations of locally endemic plants can persist in small patches (Table 2) – at least in the short term – these activities should be encouraged elsewhere in the region.

The development of the reserve system should be viewed as a catalyst for stimulating biodiversity-friendly forms of land use throughout the Succulent Karoo. These should anchor the rapidly growing tourism industry by increasing the range of experiences accessible to tourists, providing interpretative facilities, and extending the tourism season. They should also provide direct benefits to local communities, especially the impoverished inhabitants of communal lands, through direct employment on the reserves, but also through training programmes in guiding, hospitality and small-scale ecotourism initiatives.

The future of the Succulent Karoo's biodiversity – an asset of global significance – will be made more secure by designing a core system of reserves that will absorb the impacts of change. But without the involvement of human communities, the implementation and maintenance of conservation initiatives, both on and off reserves, will not be viable.

Acknowledgments

Thanks to Bob Pressey, Mandy Lombard, Phil Desmet and Allen Ellis for many hours of stimulating discussion. The research on systematic conservation planning in the Succulent Karoo has been funded by the Leslie Hill Succulent Karoo Trust, through World Wide Fund: South Africa, and South African National Parks. Bob Pressey's comments on the manuscript were very useful.

Planning is currently underway to design a reserve system for the Vanrhynsdorp bioregion. In the foreground is low succulent vegetation (vygieveld) dominated by Mesembry-anthemaceae. Endemic-rich quartz fields can be seen in the background. Photo: R.M. Cowling.

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Systematic reserve selection in the USA: an example from the Columbia Plateau ecoregion

FRANK W. DAVIS, DAVID M. STOMS AND SANDY ANDELMAN

We describe a systematic conservation planning approach for identifying a set of areas that meet specified goals for biotic representation while balancing the dual objectives of efficiency (minimum area) and site suitability. The approach was applied by The Nature Conservancy (TNC) to a regional planning exercise in the Columbia Plateau ecoregion of the north-western United States. The exercise required integrating data on species, plant communities, land ownership and other socioeconomic factors, and combined expert opinion with computer-aided site selection modelling. The set of selected areas satisfied TNC's requirements and now serves as a blueprint for ongoing conservation efforts in the region. Strengths of the approach include its explicitness, flexibility, and consideration of both biological goals and socioeconomic concerns. However, the current site selection model requires fairly sophisticated computing hardware and software, which limits its portability and use by non-specialists. We are currently working to improve model portability and to add new functionality for site prioritisation and species viability.

CONSERVING NATIVE species in human-dominated environments requires strategic planning to balance judicious siting of additional development, sustainable use of lands managed for renewable natural resources, and restoration and reservation of ample habitat to ensure the persistence of native biodiversity. Allocating land as reserves inevitably competes with the other objectives of development, resource extraction, and recreation. In order to minimise conflicts, reserve planning should occur within the broader context of comprehensive land and water use planning, zoning, and regulatory activities (Cocks and Baird 1989). Unfortunately, this has generally not been the case. In the United States and elsewhere, most parks and wilderness areas have been situated on scenic and unproductive lands without considering the value of those lands for biodiversity conservation (e.g. Scott *et al.* 1993; Pressey *et al.* 1996). Today most biological reserves are created on a case-by-case basis in response to the imminent threat of development, at which time the political and financial will is generated for direct conservation intervention. These approaches have produced a collection of protected areas that are neither biotically representative nor economically cost-effective.

Systematic approaches for identifying representative reserve systems have been advocated for more than a decade (e.g. Kirkpatrick 1983). While a variety of techniques and tools have been developed, systematic approaches generally entail: (1) an explicit statement of conservation goals, (2) evaluation of existing conservation areas with respect to those goals, and (3) identification of one or more sets of target sites that would achieve the goals with the fewest sites, least area or lowest cost (e.g. Csuti *et al.* 1997).

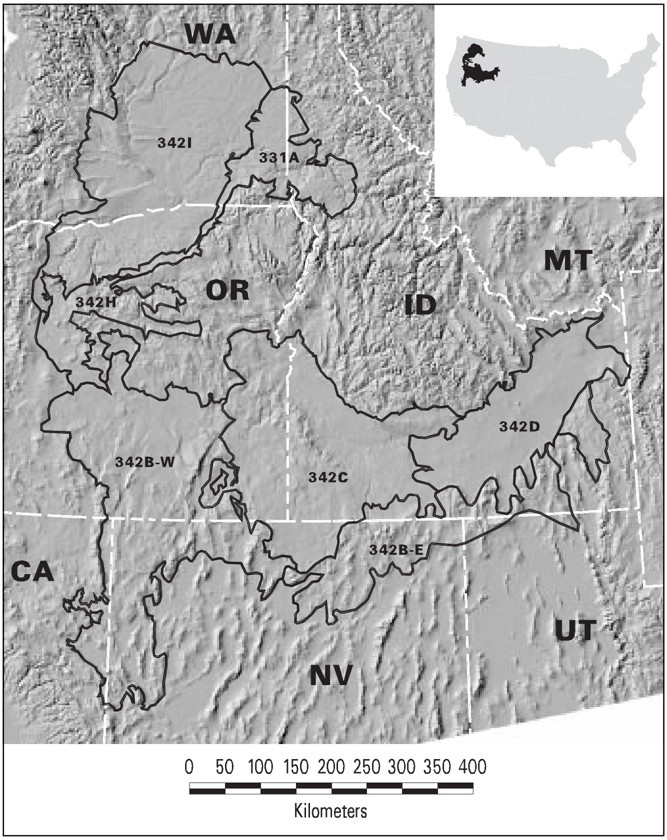


Figure 1. *Location and shaded relief of the Columbia Plateau ecoregion.*

In the United States, systematic conservation planning approaches have seen little application. This partly reflects planners' lack of familiarity with current theory and tools. Most American research on systematic reserve selection has been published in the scientific literature and proposed methods have not been tested and proven by implementation (e.g. Camm *et al.* 1996; Church *et al.* 1996; Kiester *et al.* 1996; Csuti *et al.* 1997; Gerrard *et al.* 1997). Moreover, requisite software and hardware have only recently become available and/or affordable.

In our experience, systematic approaches are initially not well-received by conservation practitioners. Even the basic step of setting explicit conservation goals can be unfamiliar and contentious. For example, there is rarely consensus on what we should be protecting (e.g. species vs. ecosystems) or on what level of protection is desirable. A common concern is that existing biological survey data are too incomplete or biased to support systematic site selection approaches. Selection models are viewed as data-driven and unable to capture in-depth personal experience and expertise. The mathematical procedures can be intimidating. Another familiar complaint is that reserve selection models are too simplistic to deal with the complex biological, socio-political, institutional and economic realities of site planning and acquisition. Thus, conservation planners tend to view systematic reserve selection approaches as purely academic exercises.

We believe that the theory and methods of conservation planning will advance more rapidly and become more useful through concerted efforts by researchers to collaborate with practitioners in applying systematic approaches to real planning exercises (e.g. Pressey *et al.* 1995). Here we summarise our experience in collaborating with The Nature Conservancy (TNC) to design a conservation strategy for the Columbia Plateau ecoregion of the north-western United States (Figure 1). In this case, modern decision support tools were adapted and applied to assist regional biologists in identifying an efficient and representative set of potential sites for biodiversity conservation. We begin with an overview of the planning method followed by its application in the Columbia Plateau ecoregion. We conclude by discussing some strengths and shortcomings of the approach and its applicability to other regions.

Overview of the planning process

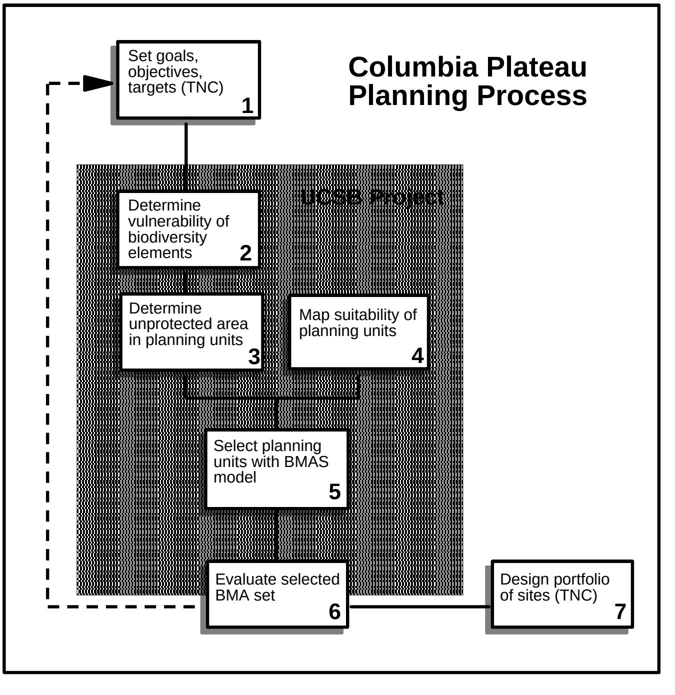
The Nature Conservancy is a non-profit, private conservation organisation that preserves biodiversity through stewardship of a network of nature preserves. TNC currently operates the largest private system of reserves in the world (more than 1,500 sites in the US alone). Recently, the organisation began a new planning initiative with the aim of developing 'portfolios' of conservation sites for each ecoregion in the US, the Caribbean, and Latin America that collectively conserve viable examples of all native species and plant communities in that region (The Nature Conservancy 1997). Both the use of ecologically defined planning regions and the adoption of biotic representation as an explicit conservation objective posed many new institutional, scientific, and technical challenges to TNC, which historically has operated on a State-by-State basis and has focused on rare and threatened species and plant communities.

TNC initially selected 11 ecoregions as top priority for development of conservation portfolios. One of these was the Columbia Plateau ecoregion (Figure 1, Bailey 1995). We collaborated with TNC scientists in this region to adapt and operate a reserve selection model that was developed specifically to generate representative portfolios over large planning regions (Davis *et al.* 1996).

Together with TNC staff we devised an iterative planning process that consists of seven basic steps (Figure 2). The first step entails specifying conservation goals, objectives, and targets. This step also includes formal definition of a spatial hierarchy of planning areas, including the planning region, sub-regions, and the areas within the region that are candidates for selection (Davis and Stoms 1996). The units of selection have generally been referred to as 'sites' in the reserve selection literature. Because 'site' has a specific and different meaning within TNC, we use the term 'planning unit' to refer to each member of a set of non-overlapping areas that were eligible for selection as new conservation areas. Generally speaking, planning units can be cells of a regular grid, watersheds, ecologically defined land units, ownership parcels, or some other system that subdivides the region into potential management areas. This is a key decision because the location, efficiency and suitability of conservation portfolios are very sensitive to the spatial properties of the planning units.

In Step 2, spatial data about the distribution of biodiversity elements are related to land management patterns to determine which biodiversity elements are currently not protected at the target levels specified in Step 1. This step amounts to a conservation 'gap analysis' of the region's biodiversity (Scott *et al.* 1993). Step 3 involves tallying the biodiversity of each planning unit to determine its potential contribution to meeting the stated conservation goals for under-represented elements. In Step 4, each planning unit is assigned a score to indicate its 'suitability' for conservation management, based on attributes such as land ownership, human population density, amount of road development, and proximity to 'core' conservation areas.

Figure 2.
Flowchart of the planning process. BMAS (Step 5) refers to the Biodiversity Management Area Selection model. BMA set (Step 6) refers to the set of biodiversity management areas resulting from Step 5.



Steps 2–4 are performed within a geographic information system (GIS). The resulting data are exported to an optimal site selection model at Step 5. This model selects a set of planning units that satisfies the representation goals with the best balance of efficiency (least area) and suitability (best quality or most manageable areas). Data generated by the model are returned to the GIS environment for further analysis and visualisation. The arrow from Step 6 to Step 1 emphasises that this evaluation can lead to changes in the specifications of goals or objectives or to refinement of a tentative plan (in the Columbia Plateau study, such refinement proved to be an important contribution to TNC's planning process). A number of alternative portfolios of conservation areas may be generated, and the results of the analysis may be re-evaluated and the process re-visited as decision makers select the portfolio of areas to be managed for biodiversity.

Addressing the values of different stakeholder groups may require defining different sets of goals, objectives, and targets and perhaps modifying the suitability scoring and then proceeding through the steps. Similarly, the process can be repeated to test the feasibility of specific policy options. The process as applied in the case study is briefly described in the next section. Stoms *et al.* (1997) provide more detail.

Conservation planning for the Columbia Plateau ecoregion

The Columbia Plateau ecoregion encompasses approximately 300,000 km² in portions of the States of Washington, Oregon, Idaho, Nevada, California, Utah, and Wyoming (Figure 1). The cool, dry climate supports steppe dominated by shrubs (*Artemisia* spp. and *Atriplex* spp.) and low perennial grasses (e.g. *Festuca* spp. and *Pseudoroegneria* spp.). Bailey (1995) subdivided the region into 7 sections of more homogeneous climatic and physiographic conditions (numbered in Figure 1). Very little land in the ecoregion has been designated for maintenance of biodiversity, while potentially conflicting land uses such as grazing and cultivation are extensive. Recently the region has received much attention from both public and private organisations, and several conservation strategies have been proposed (Wright *et al.* 1994; Merrill *et al.* 1995; DellaSala *et al.* 1996; Quigley *et al.* 1996; Vickerman 1996).

Identifying conservation goals, objectives and targets

In setting conservation goals, objectives, and targets, TNC was required to specify each of the following:

1. Biodiversity elements to be targeted for representation.
2. Representation goals to be met for each target element.
3. Areas to be classified as currently protected (the initial portfolio).
4. Planning unit boundaries.
5. Planning units to be 'fixed' (i.e. forced into or out of any solution set).

The TNC team identified two classes of target elements: vegetation alliances ('coarse-filter') and rare species and plant associations ('fine-filter') (see Jenkins 1996 for an overview of TNC's use of coarse and fine conservation filters). The current distribution of vegetation alliances (defined by structure and dominant overstory species) was mapped at 100 ha resolution by Stoms *et al.* (1998) for the US Gap Analysis Program. Data on the distribution of rare elements were provided from TNC's state Natural Heritage programs and state fish and wildlife agencies (Jenkins 1996). All plant species that were classified as rare to moderately rare or threatened

Table 1. Representation goals for vegetation alliances.

Group A:	Those alliances that typically occur in small patches in the landscape. Most of these are restricted to unusual substrate or hydrologic conditions (or maybe even disturbance regimes), and/or are limited in their distribution and so need to be protected in the Columbia Plateau ecoregion. The representation goal is to capture 50% of the area of these alliances within each section in the ecoregion if the total area in this ecoregion is small (i.e. < 500 km^2, such as *Populus tremuloides* woodland). For alliances of greater extent, the goal is set at 25% (e.g. *Pinus ponderosa* woodland).
Group B:	Those alliances which have medium coarse-filter value and occur in relatively small patches. This includes two different distribution patterns: those that are more characteristic of neighbouring ecoregions but have relatively large disjunct areas and are important within the Columbia Plateau (e.g. some montane forest types); and relatively restricted alliances that occur mainly in this region. Most alliances in Group B have total areas of < 500 km^2. The goal for this group was set at 20% representation within each section where the alliance occurs.
Group C:	All those with high to medium coarse-filter value and typically found in big patches. This includes the alliances that really 'distinguish' the Columbia Plateau from surrounding mountainous ecoregions (e.g. *Juniperus* woodlands and *Artemisia* shrublands). Most of these encompass many different floristic associations. All extend over more than 1,000 km^2 in the ecoregion. The representation goal was set at 10% within each section.
Group D:	Those types that have low value as coarse-filters and are mostly in small patches. These lie almost entirely outside of this ecoregion and were assigned no representation goal.
Group E:	Alliances or land uses of no conservation interest, such as developed and cultivated lands and exotic or planted grasslands. This group also had no representation goal.

were considered. Only rare and restricted plant associations were considered as targets.

TNC's representation goals for vegetation alliances reflected their desire to capture not only examples of the alliances but also the range of environmental variability within the distribution of those alliances. Special consideration was given to rare alliances that are endemic to this ecoregion. Also, different goals were set for alliances that were spatially extensive ('matrix' types) versus more localised alliances. Ultimately, five categories of alliances were developed and specific goals set for each category (Table 1). The TNC planning team set a goal of five occurrences of each rare vertebrate and invertebrate species in every section in which it was present. Similar goals were established for rare plant species, with some modifications based on the species' level of regional endemism. For plant associations, the goal was at least five occurrences per section.

To determine the initial portfolio of conservation planning units, TNC modified maps of land management status (Figure 3) that had been compiled by the US Gap Analysis Program (Scott *et al.* 1993; Stoms *et al.* 1998). All lands that were classified as being managed for biodiversity or for natural values (Categories I and II, 'biodiversity management areas' or BMAs) were considered part of the initial portfolio. Examples include TNC and other private preserves, some national parks, some national wildlife refuges, federal wilderness and research natural areas, and some state parks.

Existing BMAs varied widely in size, shape, and internal ecological consistency. To complete the portfolio, we first divided the remainder of the region into more consistent planning units defined by watershed boundaries. The US Geological Survey had already mapped 4,674 watersheds in the ecoregion that averaged roughly 6,500 ha in size. These watersheds were chosen as planning units because of their size, which was considered large enough to support many species' populations but small enough to be economically feasible, as well as for their hydrological integrity

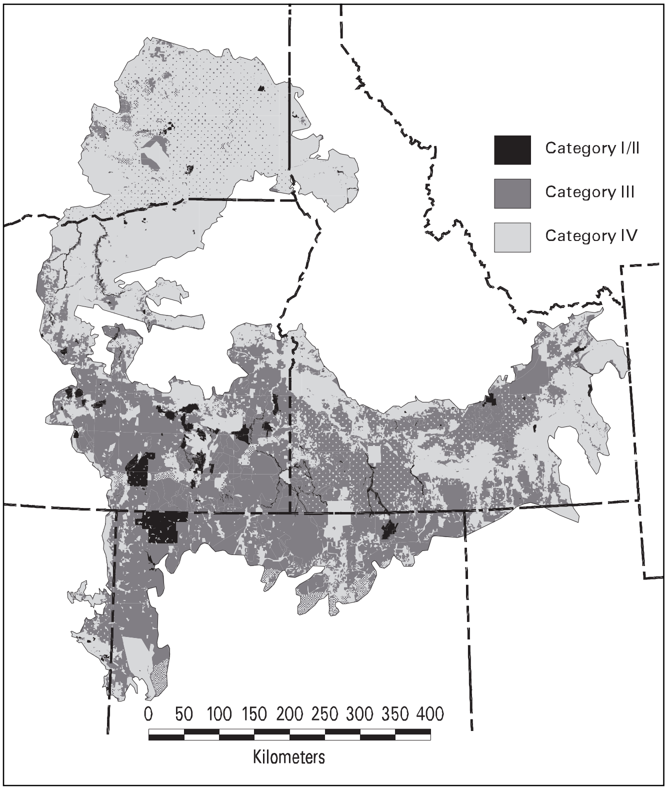


Figure 3. *Management categories in the Columbia Plateau ecoregion. Category I: Biodiversity Areas; Category II: Natural Areas; Category III: Multiple Use; Category IV: Intensive Use.*

and relative ease of recognition in the field.

In conservation planning, some areas may be considered irreplaceable or deserving of special consideration. A common means of identifying such areas is by consulting with biological experts. TNC held a workshop in January 1997 in which six panels of experts for birds, mammals, herptiles, terrestrial plant communities and species, fish, and aquatic invertebrates each independently developed its own set of priority watersheds. This process, which TNC used in part to procure data and information not already in the Heritage databases, resulted in six binary maps indicating watersheds that were selected or not selected by experts for each taxonomic group. Of the 4,674 watersheds in the region, 2,681 were identified as important by at least one panel. None of the watersheds was selected by all six panels. TNC elected to fix the 105 watersheds that were identified by four (87) or five (18) expert panels as core BMAs in the starting portfolio, regardless of their current administrative designation or mapped suitability.

Mapping the suitability of planning units

Mapping the suitability of sites for various uses has been a cornerstone of planning in the US since the technique was popularised by McHarg (1969). TNC wanted to integrate programmatic, economic, and socio-political suitability factors into the portfolio design process. In the absence of data on more direct measures of site costs or site value for development or resource extraction (e.g. Faith and Walker 1996), we employed mapped surrogates for these factors that collectively provided some indication of the site's 'suitability' for biodiversity management (Table 2). Road development and human population density were treated as indicators of habitat degradation. Aquatic integrity was a biological index based on the integrity of fish communities. Land ownership and land use/ land cover maps were used to calculate the extent of private land and land converted to human-dominated land uses in each watershed, assuming that planning units with large proportions of either would be the most difficult to protect and manage.

The site selection model used here has no explicit mechanism for considering spatial relations in selecting a set of planning units. To satisfy the planning team's desire to site new conservation areas proximal to existing reserves, we calculated the minimum distance of each watershed from existing BMAs or core areas.

Table 2. Suitability factors used in evaluating and selecting alternative portfolios of planning units.

Habitat Condition

- Roadedness as percentage of area affected by roads
- Human population density by number of people per km²
- Habitat quality based on expert opinion provided during six workshops
- Aquatic integrity index

Site Manageability

- Percentage of land in private ownership
- Percentage of land converted to human uses

Spatial Factors

- Distance from existing biodiversity management areas and core areas

Planning units nearer these 'seed areas' were scored as more suitable than those farther away. An overall suitability index was computed as the weighted sum of the individual factor values (Figure 4).

Selecting planning units as potential biodiversity management areas

Every watershed was described in terms of area, overall suitability, and biological composition. Because hundreds of biodiversity elements were not protected at the target levels (i.e. were 'vulnerable' – Step 2 of Figure 2) and we were choosing new areas from among hundreds to thousands of planning units in each section, the problem was relatively complex. We represented this decision problem as an integer-linear programming model whose objective is to optimise the selection of new conservation areas that collectively satisfy target representation levels for each vulnerable element. This multi-objective model, dubbed the Biodiversity Management Area Selection (BMAS) model (Davis *et al.* 1996), selects a set of areas that meet the predefined representation goals while balancing the dual objectives of efficiency (minimum area) and suitability. Entire planning units are selected or not selected. Technical details about the formulation of the model can be found in Davis *et al.* (1996) and Okin (1997).

Following some initial exploratory model runs, we generated a BMAS portfolio that selected 567 watersheds (56,353 km²) that satisfied TNC's target levels for 122 coarse-filter and 359 fine-filter elements (Figure 5). Taken together

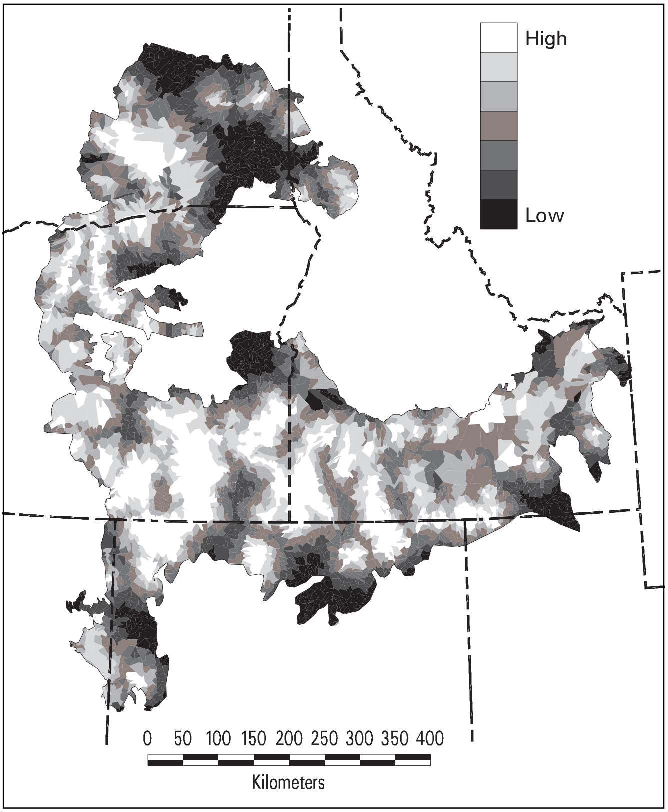


Figure 4. *Map of the overall suitability index based on default weights.*

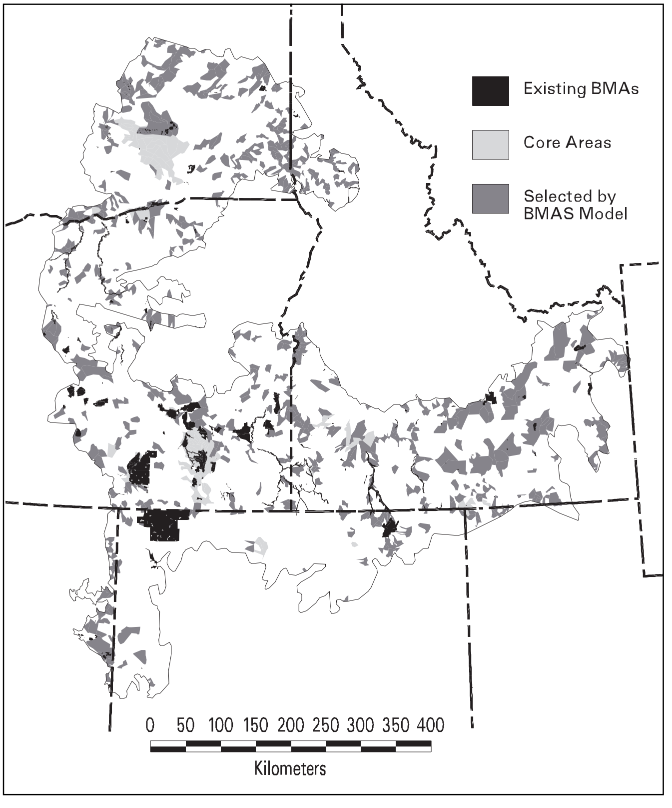


Figure 5. Map of the integrated coarse- and fine-filter portfolio selected by the BMAS model – this tentative plan was modified by TNC's planning team based on local knowledge of the selected areas.

with 9,693 km² in existing BMAs and 9,145 km² in the core watersheds identified as important by the expert panels, the land area in the portfolio amounted to 75,191 km² or 25% of the ecoregion.

Planning units selected for rare species were often heavily impacted by human activities and contributed little to meeting representation goals for vegetation alliances. Furthermore, there was little flexibility in representing rare species and plant associations. In fact, 273 of the 359 rare target elements occurred at or below the number of planning units specified in the representation goals. All of these occurrences had to be selected, regardless of watershed suitability, making 321 of the 567 watersheds in the model solution 'irreplaceable'.

Evaluating the selected set of planning units and designing the final portfolio

Solutions to the BMAS model were imported into the GIS so analysts could evaluate the selected planning units in relation to other GIS data (e.g. land ownership or management). Such an evaluation can lead to modification of the initial decision rules and generation of new alternatives. It can also lead to refinement of the set of areas in the recommended portfolio (Figure 2, Step 7). In this case, the TNC planning team did not generate alternative portfolios, but did make modest adjustments to the portfolio based on first-hand knowledge about the suitability of some of the selected planning units.

Figure 6 shows how well the portfolio satisfies the initial representation goals for the rarest elements of biodiversity. We should add that being 'selected' for the regional portfolio does not necessarily imply that an entire watershed must be purchased. The actual biodiversity management strategy for a site is determined during implementation and could merely entail monitoring of a rare ecosystem or a simple modification in management practices.

Conclusions

At the outset of this paper we asserted that reserve planning should ideally take place within the broader context of regional land and water planning and regulatory activities. The case study described here was an internal planning exercise of The Nature Conservancy. Involving the various stakeholders at the outset would have been a much larger and complex undertaking that would likely have led to a somewhat different portfolio and a clearer prioritisation of watersheds for conservation actions. TNC recognises that implementation of the regional portfolio must engage public land management agencies and private landowners. The portfolio is considered an initial blueprint subject to ongoing revision depending on local obstacles and opportunities and changes in land use in the region. In principle the modelling approach used here could be applied to update and maintain the portfolio.

TNC approached the planning exercise in the Columbia Plateau ecoregion as a possible prototype for the other 62 ecoregions of the United States. The planning process required a formal, explicit statement of goals, definitions, conservation targets, and measures of performance. An important aspect of the exercise was a consistent and explicit representation of expert knowledge. In spite of the large size and biological complexity of the region and the large number of elements and factors that were considered, TNC was able to synthesise expert scientific knowledge and existing geospatial data. Computer decision support tools were essential in assembling a portfolio of biologically representative and suitable planning units. According to the TNC planning team, the new portfolio satisfied their intention for coarse-filter as well as fine-filter representation, corroborated their priorities for some areas, and improved their knowledge of others.

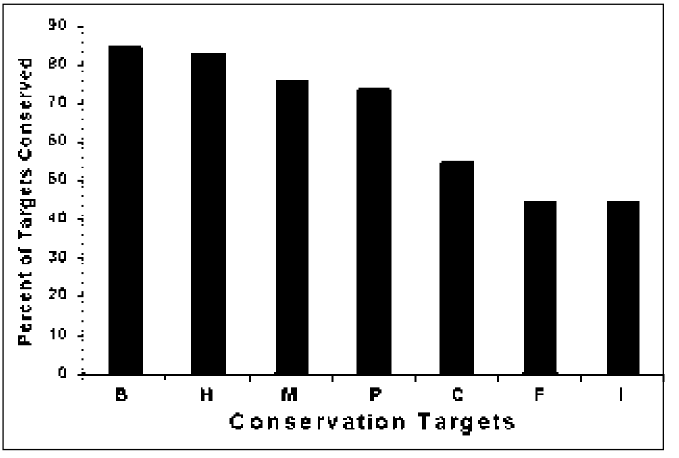


Figure 6. Percent of target elements (i.e. vulnerable species and rare plant community associations) occurring in the proposed conservation portfolio. B=birds; H=herptiles; M=mammals; P=plants; C=rare plant communities; F=fish; I=invertebrates. Target levels of representation fall short of 100% because, in most cases, the number of known mapped occurrences was less than the target level of representation. This information helped TNC identify future inventory needs.

The planning process used here has several deficiencies. The need to operate the BMAS model in our research lab in Santa Barbara eliminated the possibility of TNC's planning team using the model as an interactive tool for understanding and decision support. The process lacked a formal accounting of potential bias and uncertainties caused by uneven data quality and expert knowledge. There was no prioritisation of the selected planning units for conservation efforts. Potential changes in land use and environmental factors such as regional climate were not considered explicitly. More generally, we did not attempt to test the viability of any of the target elements at any of the planning units or over the collection of planning units, which would have required scenarios of future habitat conditions for both protected and unprotected sites in the region. Other systematic approaches also suffer from many or all of these deficiencies, and issues such as uncertainty, optimal staging of implementation, and improving portfolio design for viability are all areas of active research.

Obviously, implementing a representative system of protected areas is highly constrained by socioeconomic and political factors. We attempted to address these assorted factors by considering the dual objectives of area (efficiency) and suitability in the BMAS model. The suitability index was computed to integrate existing digital geospatial data on roads, human settlements, and land ownership and use. These variables and the composite index are crude surrogates for competing land use pressures and constraints, which are usually governed by very local factors that we were unable to capture over such a large planning region. It was possible to integrate some local knowledge during a site-by-site evaluation of the portfolio by the planning team, which rejected some of the planning units in the initial solution from the computer model and replaced them with biologically comparable but more feasible areas. Incorporating detailed knowledge at this step reduced the effort by the planning team, which only had to deal with reviewing candidate areas rather than trying to document everything they knew about the entire pool of planning units.

The planning process outlined here is generic enough to be applicable in most geographic regions and for most conservation organisations. The only requirements are that goals and objectives can be stated precisely and that the study area can be divided into a set of planning units for which spatial data on biological and non-biological features are available. Presently the BMAS model and the GIS data processing require sophisticated commercial software. The authors are currently working on decision support software for regional portfolio design and site prioritisation that is more accessible to land planners.

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Applications of irreplaceability analysis to planning and management problems

R.L. (BOB) PRESSEY

One of the outcomes of research and development in conservation planning over the last few years is the idea of irreplaceability. Irreplaceability refers to the importance of an area (e.g. a farm, watershed or forest fragment) for achieving an explicit conservation goal for a country, a region or a single protected area. A map of irreplaceability is a map of the options for achieving some desired outcome in planning new protected areas or managing existing ones. For some areas there are no replacements – the goal cannot be achieved without them. For other areas, there are varying numbers of replacements. This information lets planners and managers explore alternative ways of achieving their goals. It also lends itself to negotiation among interest groups as to how a conservation or management goal should be achieved. Another application of irreplaceability is to set conservation priorities by indicating how easily conservation action or management zoning could be relocated if a particular area were to become unavailable or have its natural values destroyed. This article summarises the ideas and findings from about seven years' work on irreplaceability. It illustrates two recent applications of the idea to parts of New South Wales and discusses some potential future uses in conservation planning and the management of protected areas.

IRREPLACEABILITY ANALYSIS was developed in response to a limitation of the reserve selection algorithms which have been used extensively since the early 1980s. These algorithms can quickly select a set of areas to achieve a nominated conservation goal but provide little or no information on the potential contribution to that goal of the unselected areas in a region. Consequently, most of them do not indicate optional replacements for selected areas in case these become unsuitable or unavailable for conservation management. None of them indicate the degree of irreplaceability of selected areas. The alternative sets of areas that can achieve a conservation goal in a region can number in the hundreds or even hundreds of thousands. Few conservation planners would choose to explore so many alternative configurations of conservation systems. Nevertheless, information on the spatial pattern of optional conservation areas in a region and the number of possible replacements for any particular area has obvious value in dealing with constraints on the location of new conservation areas. Both types of information are provided by a map of the irreplaceability of each potential conservation area in a planning region.

What is irreplaceability?

Like selection algorithms, irreplaceability analysis can be applied at any geographical scale, from continents to individual protected areas. The areas being considered for reservation or some other form of conservation management can be any discrete parts of the landscape – forest fragments, wetlands, farms, watersheds, management subdivisions of production forests, or arbitrary grid cells. Also like selection algorithms, analysis of irreplaceability is driven by a goal in the form of a set of quantitative targets for the natural features (e.g. ecosystems, habitats, species) in a region. The targets can be framed as numbers of known occurrences (e.g. at least one record of each species), areas (e.g. a minimum extent of each vegetation type), minimum population sizes, or relate to predicted probabilities of occurrence. Each of the natural features in the study area (species, habitats, ecosystems etc.) is given its own target to reflect planners' decisions about how much should be contained in reserves or otherwise protected from damage or loss. Ideally, decisions on the relative size of the target for each feature are based on considerations such as rarity and vulnerability to threatening processes such as clearing, logging or mining.

Once targets are nominated, the irreplaceability of an area can be defined in two ways (Pressey *et al.* 1994), both of which take into account the extent to which targets have already been achieved in existing conservation areas:

1. The likelihood that the area will be required as part of an expanded conservation system that achieves the set of targets.
2. The extent to which the options for achieving the set of targets are reduced if the area is unavailable for conservation.

Irreplaceability defined in this way is not binary – both definitions identify a spectrum of values from totally (100%) irreplaceable to zero irreplaceable (Figure 1). Areas can have any value between these two extremes. If an area is totally irreplaceable, then no matter how a system of conservation areas is designed for a region, it will have to include that area. Put the other way, if that area loses its conservation values because of development or overuse, one or more of the conservation targets for the study area will become unreachable. Areas with progressively lower irreplaceabilities have progressively more replacements in the region, less likelihood of being required as part of a system of conservation areas, and less impact on the achievement of targets if destroyed or unavailable for conservation. Areas with zero irreplaceability contain only features that have already had their conservation targets met in existing protected areas.

Areas with total or high irreplaceability become the nodes of an expanded system of conservation areas, around which other areas can be grouped in the interests of reserve design. Choices between areas with lower irreplaceabilities can be resolved according to location, size, condition, cost and other factors that influence the persistence of natural features and implications for ongoing management.

Related terms and ideas

The original work on irreplaceability (Pressey *et al.* 1993, 1994) was applied to the semi-arid rangelands of western New South Wales. The areas being considered were pastoral holdings and the natural features were landscapes, most of which were extensive. Those landscapes that were restricted in area seldom occurred in the same pastoral holding. Work on the same idea in regions with very large numbers of coincident, narrowly endemic plant species required a different interpretation. In the arid Succulent Karoo biome of South Africa, irreplaceability has been used to mean the number of species unique to an area (Lombard *et al.* in press). This highlights a weakness in the original definition – in some regions, the majority of areas required to achieve a set of conservation targets can be totally irreplaceable but will vary greatly in the numbers of unique species that would remain at risk if they were not protected (see also Rebelo 1994). A similar problem has arisen in conservation

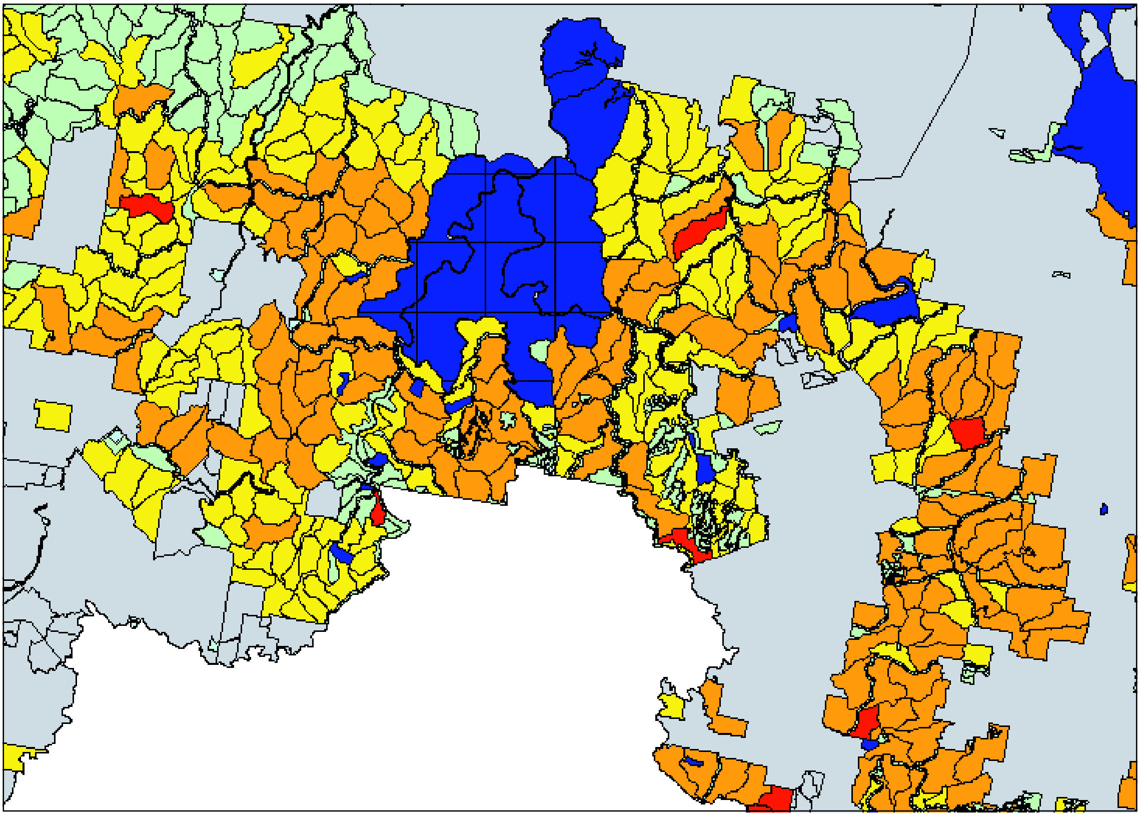

Figure 1. *An irreplaceability map of part of north-eastern New South Wales. Existing reserves are dark blue. The coloured areas are units of management of public forests considered as additional reserves during negotiations in 1996. These average 250 ha in size. Irreplaceability values range from red (highest) through brown, orange, yellow, pale green and pale blue (lowest). The irreplaceability pattern will change if conservation targets for features are altered. Grey areas are tenures excluded from the negotiations.*

assessments in the forests in eastern New South Wales since 1996 (below) and has been addressed by using an index called 'summed irreplaceability', or the sum of the irreplaceabilities of an area, estimated separately for each of the features it contains (Figure 2).

Irreplaceability can be, but is not necessarily, related to measures of rarity (reflecting low abundances or restricted distributions of species or other natural features) and endemism (reflecting the number of features unique to an area). Endemic features targeted for conservation will always confer total irreplaceability and the occurrence of rare features will often be related to high irreplaceability. But the dependence of irreplaceability values on rarity and endemism will be strongest when conservation targets are one occurrence of each feature. In most real-world applications, targets are multiple occurrences (e.g. of species) or areas (e.g. of vegetation types). In these cases, the connection between rarity or endemism and irreplaceability values can be weak. Irreplaceability for area targets depends less on the frequency of a feature in a region than on whether an area contains a small or large occurrence of a feature relative to its target and relative to other occurrences in the region. Irreplaceability is always target-specific. Rarity and endemism are biogeographic concepts unrelated to particular conservation targets.

The need to predict irreplaceability in real-world applications

Although the concept of irreplaceability is straightforward, its measurement is not. The irreplaceability of an area depends on:

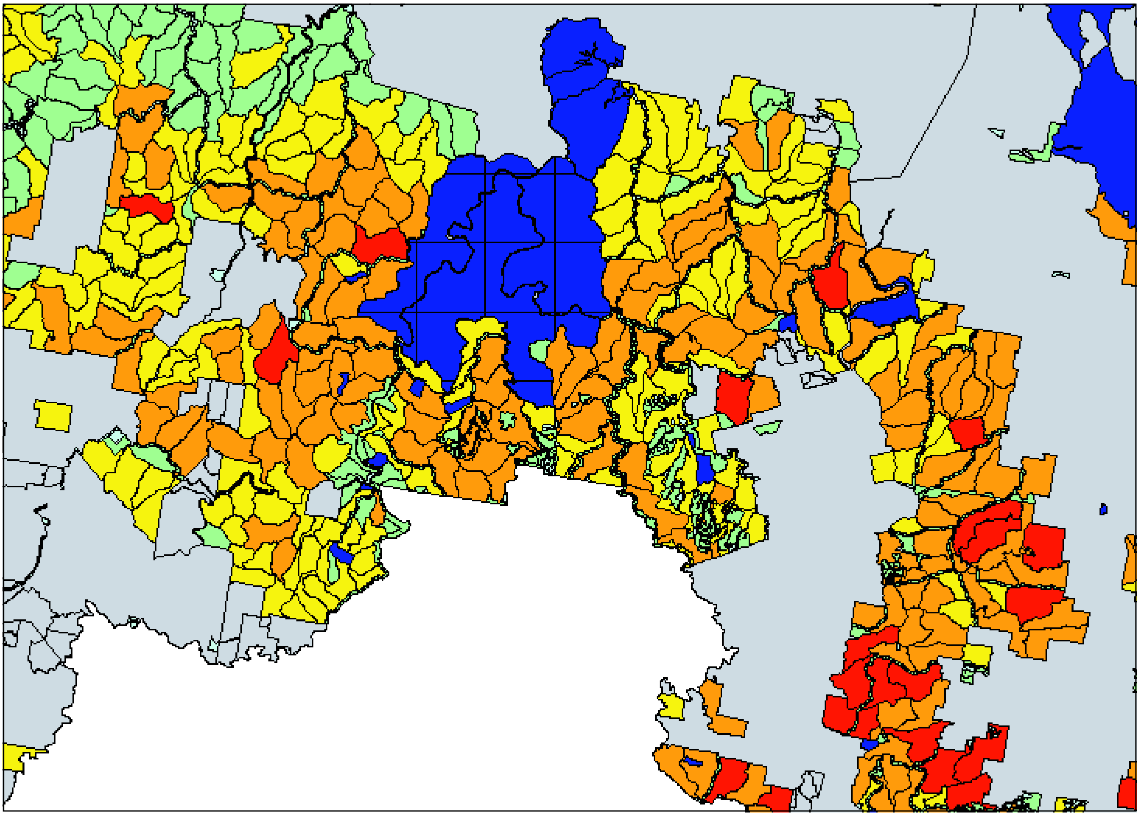

Figure 2. Variation in summed irreplaceability for the same region as in Figure 1. Summed irreplaceability is the total of irreplaceability values of each compartment for all the features (species, vegetation types) it contains. Colours as for Figure 1.

- The list of natural features occurring in the area.
- The conservation targets set for each of those features.
- How many other areas contain each of the features occurring in the area.
- How large the occurrences of those features are in other areas, relative to the occurrences in the area being considered.

Direct measurement of irreplaceability is a combinatorial problem. It involves looking at all the possible combinations of areas in a region to see how many of those combinations could achieve all the conservation targets set for natural features. When the combinations that are 'representative' are lined up (the ones that achieve all targets and can therefore be considered as alternative systems of protected areas), the irreplaceability of a single area is the percentage of the representative combinations (or the percentage of alternative protected area systems) in which it occurs. A totally irreplaceable area occurs in all representative combinations either because it contains one or more unique features or because it contains sufficiently large occurrences of one or more features that the conservation targets for those features cannot be met without it.

Such a combinatorial problem is simple for very small data sets, say for 'regions' of ten or 20 areas. As the size of the data set expands to real-world dimensions (say to 1,800 areas and 430 natural features in part of north-eastern New South Wales – Pressey 1998), an astronomical number of combinations would have to be analysed to directly measure irreplaceability. The job is far too large even for the most powerful modern computers. A predictive approach is therefore necessary if irreplaceability analysis to be used to solve real-world problems. Just as importantly, the predictor must work quickly. If decision-makers are using irreplaceability interactively, they want to see the answer to a question in seconds, not hours.

Much of the work on irreplaceability has gone into developing and testing predictive approaches. Early predictors (Pressey *et al.* 1994, 1995) have now been superceded by a powerful statistical approach (Ferrier *et al.* submitted) that operates fast enough for the irreplaceability of 15,000 areas to be recalculated and redisplayed in about 30 seconds.

Applications of irreplaceability

Only some of the potential applications of irreplaceability analysis have been realised (Box 1). In the following sections, two recent applications to real-world problems are described. Both examples are from New South Wales, but the same ideas are currently being explored and applied elsewhere in Australia as well as in South Africa, South America, the USA, and Canada. Applications in Australia include both terrestrial and marine environments.

Using irreplaceability to negotiate new conservation areas

The early work on irreplaceability (Pressey *et al.* 1994) recognised the need for an interactive, rather than static, analysis. This is because, as decisions are made to conserve particular areas, the irreplaceability values of some of the unprotected areas change. Conservation action, actual or notional, takes some features closer to their targets. Consequently, other areas containing those features have "less to offer" to the regional conservation goal and their irreplaceability values can decrease. Later work (Pressey *et al.* 1995) developed a prototype interactive system that did two things: (1) it linked the calculation of irreplaceability to a GIS screen display to show existing reserves, other areas for which conservation action was planned, and colour-coded irreplaceability values of all the remaining areas; and (2) accepted decisions, recalculated irreplaceability of the unconserved parts of the landscape, and refreshed the display whenever the user wished. This provided a working example of a decision-support system that facilitated negotiation over land use. It also required a predictor of irreplaceability that could deal quickly with a regional data set.

For a year or so, the prototype system was an idea looking for an application. Its chance came in the middle of 1995 when the New South Wales Government laid out its forest policy for the State. This was to be implemented in two stages. First, there would be an interim assessment to identify areas highly likely to contribute to an expanded reserve system in the eastern forests. These would remain unlogged until their values had been confirmed. Second, the interim process would be followed by a series of comprehensive assessments that would finalise the boundaries of new, permanent reserves. The government decided that the prototype interactive system should be developed to form the basis of high-level negotiations between major stakeholders in the forests. The prototype was stripped down and rebuilt to be faster and more powerful with a view to supporting negotiations in April and May 1996.

The new interactive system (now called C-Plan) performed well for four weeks of intensive negotiations, involving two teams of stakeholders working in

Box 1. Demonstrated (shaded) or potential applications of irreplaceability analysis in planning new protected areas or managing existing ones.

1. A 'one-off' picture of irreplaceability (Pressey *et al.* 1994; Kiester *et al.* 1996; Csuti *et al.* 1997) as a guide for decisions about the impacts of development projects or the locations of new reserves or protective zonings. Totally irreplaceable areas, if lost to development, will compromise to some extent the conservation goal for a region. They are also essential components of an expanded system of protected areas. Areas with progressively lower irreplaceability have a correspondingly lower likelihood of being needed as part of a conservation system. Similarly, their loss to conservation has progressively less impact on the planning goal.

2. Exploration of alternative conservation scenarios, defined by different sets of conservation targets, different starting points (e.g. areas considered mandatory or unavailable for conservation), and different data sets (Freitag *et al.* 1998; Pressey 1998). Comparisons between the resulting patterns of irreplaceability can help to refine regional conservation goals, illustrate the outcomes of alternative policies, and understand the implications of type and quality of data.

3. Application as a component of interactive planning software that recalculates and redisplays the pattern of irreplaceability as decisions about new conservation areas proceed (Pressey *et al.* 1995; RACAC 1996; Pressey 1998). As decisions are made about particular areas, the pattern of irreplaceability of the unconserved areas is recalculated and redisplayed to update the remaining options. This process has been used extensively in New South Wales and elsewhere to design systems of new conservation areas.

4. As a guide to the feasibility of changes to a conservation plan (Pressey *et al.* 1995). Even the most carefully designed systems of conservation areas are likely to need modification as the opportunities and constraints for conservation action on the ground become apparent during implementation. If the initial irreplaceability patterns of areas, both selected and unselected for conservation, are displayed, planners can see the varying options for replacing selected areas with others. Totally irreplaceable areas are non-negotiable – if they are not given some appropriate level of conservation management, the plan will not achieve its goal. Other initially selected areas can be replaced with others if conservation action is pre-empted by habitat loss, or if they prove difficult to protect. The scope for replacing these areas depends on their irreplaceability scores, subject also to considerations of reserve design and potential management problems.

5. Combined with information on vulnerability or threat, irreplaceability provides a basis for setting priorities in both space and time (Cole and Landres 1996; Pressey 1997; Pressey and Taffs, submitted). Using this rationale, areas that are both highly irreplaceable and highly vulnerable to destruction or disturbance have highest priority – they are most likely to be damaged (or will be damaged soonest) and the consequences of this damage will most seriously compromise the conservation goal. This is essentially the same rationale applied in recent global assessments of priority regions (Myers 1988, 1990; Sisk *et al.* 1994; Mittermeier *et al.* 1998). It is also analogous to priority-setting exercises within regions that have used species endemicity instead of irreplaceability (e.g. Cowling *et al.* 1998; Lombard *et al.* 1999).

6. Irreplaceability analysis could help in the preparation of management plans or the location of management zonings within established protected areas. In this application, the 'region' of interest would be defined by the boundaries of the protected area. The management goal would be based, at least partly, on the need to retain minimum areas or numbers of localities (management targets) of vegetation types or species. Information on the exposure and vulnerability of vegetation types and species to visitor use, fire, and other potential disturbances would be combined with the irreplaceability of parts of the protected area for achieving management targets. Areas with high irreplaceability and high vulnerability would require very careful management actions. Less irreplaceable areas would be more likely to have replacements away from disturbance. They would be candidates for 'sacrifice' areas to accommodate the needs of visitors or could be replaced with other suitably zoned areas in the event of unplanned adverse impacts. Like regional conservation assessments (2), the location and design of management actions could benefit from negotiation of options by interest groups.

7. With goals defined by areas of terrain or soil types to be rehabilitated, irreplaceability would also indicate the options in the landscape for restoration of habitats. The resulting irreplaceability of farms or other management units could be combined with information on the desired locations of habitat corridors between existing fragments or the locations of special features such as groundwater recharge zones (Pressey *et al.* 1995) to produce an action plan for habitat reconstruction.

8. Similar to 6, above, irreplaceability analysis could also guide the cost-effective design of a field survey where the goal of the survey is to locate sampling sites in a range of vegetation types or abiotic environments. Spatial options for sampling, combined with information on access, would allow a set of areas to be identified that allowed the survey goal to be achieved with minimum travelling.

parallel on different regions, and covering a total of 2.4 million ha of public forest. The photo aboveshows one of these negotiation groups in action. The extensive preparations for this process, setting of conservation targets, the details of the negotiations themselves, and the political aftermath are described in detail elsewhere (Pressey 1998). The use of C-Plan made irreplaceability a commonly used term in environmental circles. More importantly, the system was highly successful as a decision-support tool to resolve a difficult, contentious issue. All parties remained in the process till the end, even though some had been very antagonistic previously. The outcomes included nine new national parks and nature reserves, about 816,000 ha of forest temporarily deferred from logging, extensive new wilderness areas, and agreements on the supply of hardwood for five years.

Negotiations in progress over new forest conservation areas, Sydney, 1996. Photo: Resource and Conservation Assessment Council.

Although the development of C-Plan has continued since the end of the 1996 negotiations, its application in subsequent regional forest assessments to identify final reserve boundaries has been more problematic. The reasons lie not with the software but with factors such as the negotiation process being politicised, unresolved arguments over conservation targets, and a lack of cooperation between stakeholders when the stakes are very high (Finkel 1998a, b). Even so, C-Plan and the interactive application of irreplaceability played a major role in both subsequent rounds of the forest debate. It was used to locate and design extensive new reserves in both the south-east (late 1997) and north-east (late 1998) of the State. Increasingly, C-Plan is operated not by one or two experts in a major negotiation process but by individual agencies and non-government organisations, emphasising its importance in exploring the options for conservation and development in a region.

Using irreplaceability to identify conservation priorities in the face of ongoing habitat loss

One of the common realities in all parts of the world, and at local, regional or global scales, is that the agents of biodiversity loss do not stop because someone is working on a conservation plan. As a result, while systems of conservation areas expand (often slowly because of limited resources), the features that need protection are being lost at varying rates by threatening processes such as clearing, cropping, urbanisation, mining, and introduced plants and animals. Therefore, a practical approach to setting priorities for conservation must often deal with options in time as well as options in space. A way of making such an approach operational is to define priority areas as having two characteristics – high irreplaceability and high vulnerability to loss or damage. Vulnerability can refer to the likelihood of a species or a vegetation type being lost over a certain time period, or it can refer to how soon it will be affected

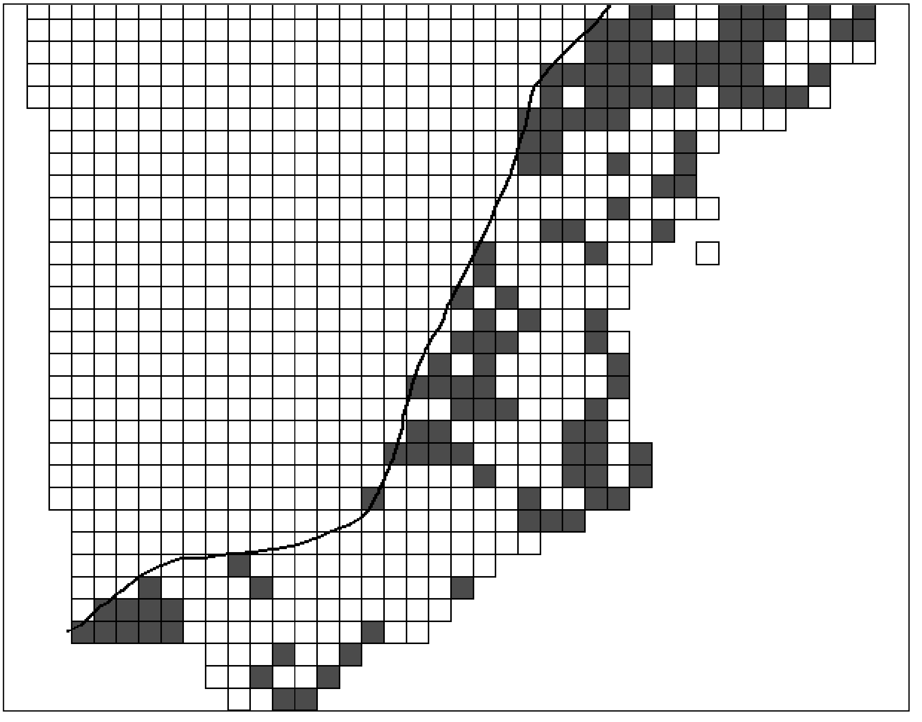

Figure 3. Priority conservation areas in the Western Division of New South Wales. Priority areas are those with highest irreplaceability for achieving regional conservation targets and highest vulnerability to clearing. The heavy curved line marks the western climatic limit of clearing and dryland cropping in the Division. Areas inland of this line are used almost entirely for grazing on native rangelands.

or lost altogether. Areas with highly vulnerable features and which are also highly irreplaceable are the highest priorities for conservation in a region. They are very likely to lose their natural values, and the consequences of that loss will be most serious for the achievement of regional conservation targets. In other words, conservation targets will be compromised to the smallest extent if conservation action is prioritised in this way.

Although irreplaceability analysis is relatively new, there are precedents for the idea of setting priorities according to these two considerations. Irreplaceability has been substituted by endemism in other regional assessments (Cowling *et al.* 1999; Lombard *et al.* 1999) or has remained qualitative (Cole and Landres 1996). Several global assessments have also taken the same conceptual approach (Myers 1988, 1990; Sisk *et al.* 1994; Mittermeier *et al.* 1998).

The combination of irreplaceability and vulnerability has recently been applied to the Western Division of New South Wales (Pressey and Taffs submitted). This is a semi-arid region of about 320,000 km^2. In our study, we set conservation targets for each of 248 land systems that had been mapped at a scale of 1:250,000. The targets reflected the natural rarity of the land systems as well as the likelihood that they would be cleared for cropping or pastoral use. We first calculated the irreplaceability of about 800 areas across the Division (using arbitrary grid cells to avoid identifying individual farms at this stage) according to the mix of land systems they contained. We then rated the vulnerability of each area based on the suitability of its land systems for clearing. Finally, we identified areas with the highest priorities for conservation in the Division as having high irreplaceability and high vulnerability (Figure 3). High-priority areas are largely in the eastern and southern parts of the region, reflecting the low rainfall of the interior which constrains intensive land use. The process of reservation in the Division will be gradual. Focusing reservation and other conservation action on these priority areas will minimise the extent to which regional conservation targets are compromised by clearing before they are fully achieved.

Conclusions

Irreplaceability is an intuitive concept. People involved in using C-Plan for forest negotiations and other regional assessments have had no problem grasping the idea and understanding its usefulness in planning. Similarly, the notion of setting conservation priorities according to irreplaceability and vulnerability has been accepted by many conservationists. Much of the research and development surrounding irreplaceability has been to quantify it and to make it operational in decision-support systems.

Analysis of irreplaceability is not a panacea for all conservation problems, but it helps planners and managers in three main ways:

- It allows people to explore the implications of different conservation scenarios.
- It identifies areas that are important for achieving national, regional or local conservation goals.
- It can facilitate the resolution of debates over the location and design of conservation areas.

There is much scope for extending the real-world applications of irreplaceability analysis (Box 1) and a need for further work to refine the measurement of irreplaceability and its use within decision-support systems. My group is actively continuing this research and, as our collaboration with planners, managers and other scientists expands, we are encountering new problems and having to find new solutions.

Acknowledgements

C-Plan, the Service's interactive planning system that incorporates irreplaceability, has been developed for more than three years by Matthew Watts. Tom Barrett has spent considerable time assisting with development of the system, as well as testing, validating, demonstrating, and applying it to real-world problems. The new irreplaceability predictor is the brainchild of Simon Ferrier. Matt, Tom and Simon continue to be enjoyable and stimulating colleagues.

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Résumés

Une approche à la mise en place d'une structure systématique de zones protégées en Guyane

KAREN S. RICHARDSON ET VICKI A. FUNK

La Guyane est un petit pays sur la côte nord de l'Amérique du Sud. Elle représente une opportunité unique de mettre en place une structure représentative de zones protégées pour préserver son immense diversité d'habitats et d'espèces. La Guyane a une faible population concentrée sur la côte et n'a ouvert que récemment l'exploitation de ses ressources naturelles, de sorte que ses écosystèmes sont intacts. Cet article décrit une approche à la mise en place d'une structure de zones protégées en Guyane reposant sur les caractéristiques des distributions d'espèces. La distribution de la biodiversité était très méconnue avant une étude effectuée en 1995. Les caractéristiques de biodiversité connues à partir de cette étude et résumées ici, s'appuient sur de nombreuses années de collecte et de confirmation de données récupérées à partir d'autres campagnes. Outre la définition d'une approche analytique, l'article comprend une évocation des contraintes du monde réel en ce qui concerne la mise en place de zones protégées. D'autres aspects de cette étude sont encore en cours et comprennent la comparaison de différents substituts de biodiversité servant de base à la planification de la protection, à l'analyse des différentes menaces sur la biodiversité, et aux évaluations des priorités de conservation à différentes échelles dans l'espace.

Planification durable – mise en place systématique de réserves dans le désert de karou succulent au sud de L'Afrique

RICHARD M. COWLING

Cet article évoque une nouvelle approche à la planification systématique de la préservation qui permet d'éviter certaines des limites des travaux précédents dans ce domaine. Une grande partie des développements de méthodes de planification de préservation se sont concentrées sur la représentation des caractéristiques de biodiversité (par exemple listes d'espèces, types de végétation) dans les réserves. Ils sont généralement partis de l'hypothèse que la mise en place de nouvelles réserves proposées serait rapide, de sorte qu'il n'était pas nécessaire d'envisager quelles zones proposées devraient bénéficier en priorité d'une réelle protection sur le terrain. Cette hypothèse est loin de la réalité dans laquelle la mise en œuvre du cadre d'une réserve est principalement progressive et ou la perte continuelle de biodiversité pendant le processus de mise en place peut compromettre la possibilité d'atteindre les objectifs de représentation. Une stratégie de localisation et de définition de nouvelles réserves est donc nécessaire pour promouvoir les processus naturels de préservation, ainsi que les caractéristiques de biodiversité, et pour guider la mise au point d'un calendrier d'actions de préservation en tenant compte de ressources limitées. Dans cet article nous présentons un cadre conceptuel et un protocole de mise en place d'une structure de réserve qui prend explicitement en compte à la fois les caractéristiques naturelles et les processus. De manière tout aussi important, l'approche décrite part de l'hypothèse d'une mise en place progressive de nouvelles réserves, qui implique des interventions programmées au moment opportun pour garantir la conservation de caractéristiques et de processus irremplaçables qui sont particulièrement exposés à des menaces. La région étudiée est le biome du désert de Karou Succulent au sud de l'Afrique, une région désertique sensible connue à l'échelle internationale, qui se caractérise par sa diversité exceptionnelle et la rareté de ses espèces de plantes. L'étude décrite ici n'est pas théorique - elle identifiera les priorités essentielles de préservation dans une région et constituera un guide à l'attribution des fonds disponibles à ces zones.

Sélection systématique de réserve aux états-unis : l'exemple de l'écorégion du plateau de Colombie

FRANK W. DAVIS, DAVID M. STOMS ET SANDY ANDELMAN

Nous décrivons une approche systématique à la planification de la préservation pour identifier un ensemble de zones qui satisfont les critères de représentation biotique tout en conservant un équilibre entre les deux objectifs d'efficacité (zone minimum) et d'adéquation du site. Cette approche a été appliquée par l'Association de protection naturelle (T.N.C) dans le cadre d'un exercice de planification régionale sur la région écologique des plateaux de Colombie au nord-ouest des États-

Unis. Cet exercice a nécessité l'intégration de données sur les espèces, les communautés de plantes, la propriété des sols et d'autres facteurs socio-économiques, et associe une opinion d'experts avec une modélisation sélective assistée par ordinateur du site. L'ensemble des zones sélectionnées satisfont les critères de la T.N.C. et sont maintenant utilisées à titre de principes directeurs dans le cadre d'efforts de préservation dans la région. Les points forts de l'approche comprennent la clarté, la flexibilité, et la prise en compte à la fois des objectifs biologiques et des questions socio-économiques. Cependant, le modèle de sélection de site actuel nécessite des outils informatiques et des logiciels sophistiqués, ce qui limite les possibilités de transposition et son utilisation par des non spécialistes. Nous travaillons actuellement à l'amélioration de la possibilité de transférer les modèles, et à mettre en place de nouvelles fonctions de définition de sites prioritaires et de viabilité d'espèces.

Application de l'analyse d'impossibilité de remplacement aux problèmes de planification et de gestion

R.L. (Bob) Pressey

L'un des résultats de la recherche et du développement dans le domaine de la planification de la préservation au cours des dernières années est l'idée d'une impossibilité de remplacement. L'impossibilité de remplacement se rapporte à l'importance d'une zone (c'est-à-dire une exploitation agricole, un bassin versant ou un fragment de forêt) dans le cadre de l'atteinte des objectifs de préservation claire pour un pays, une région où une zone unique protégée. Une carte d'impossibilité de remplacement est une carte comprenant les options qui vise à atteindre un résultat voulu dans de nouvelles zones de planification protégées, ou à la gestion de zones existantes. Pour certaines zones il n'y a pas de remplacement, l'objectif ne peut-être atteint sans elles. Pour ces zones, il existe un nombre variable de remplacements. Ces informations permettent aux planificateurs et aux gestionnaires d'explorer différentes méthodes pour atteindre leurs objectifs. Elles se prêtent également à la négociation entre les groupes d'intérêt concernant la façon d'atteindre un objectif de préservation et de gestion. Une autre application de l'impossibilité de remplacement est la définition de priorités de conservation en indiquant dans quelle mesure il serait possible de replacer des zones d'actions de préservation et de gestion si une zone spécifique devenait indisponible ou voyait ses atouts naturels détruits. Cet article résume les idées et découvertes découlant de sept années de travail sur l'impossibilité de remplacement. Il illustre deux applications récentes de cette idée à certaines parties du Nouveau Pays de Galles du Sud et évoque des utilisations potentielles futures dans le cadre de la planification de la préservation et de la gestion de zones protégées.

Resumenes

Una aproximación para el diseño de un área protegida sistemáticamente en Guyana

Karen S. Richardson and Vicki A. Funk

Guyana es un pequeño país en la costa norte de Sudamérica que presenta una oportunidad única a la hora de establecer un sistema representativo de áreas protegidas para conservar su enorme biodiversidad de hábitats y especies. Guyana tiene una pequeña población concentrada en la costa y acaba de comenzar la explotación de sus bienes naturales, con lo que la mayoría de su ambiente se encuentra intacto. Este artículo describe un enfoque de diseño de un sistema de áreas protegidas en Guyana basado en patrones de distribucion de especies. Poco se conocía en cuanto a la distribución de la biodiversidad con anterioridad a un estudio llevado a cabo en 1995. Los patrones de biodiversidad conocidos a partir de este estudio y aquí recogidos se basan en la adquisición y consolidación de datos de campañas de varios años y personas. Además de esquematizar el enfoque analítico, el artículo discute también las limitaciones en el mundo real a la hora de establecer áreas protegidas. Otros aspectos de este estudio están aún en ejecución e incluyen comparaciones de diferentes sustitutos de biodiversidad como base para la planificación de la conservación, análisis de diferentes amenazas a la biodiversidad y evaluaciones de prioridades de conservación en diferentes escalas territoriales.

Planificación para un diseño de reservas persistente –sistemático reserve en el desierto de Succulent Karoo en Sudáfrica

RICHARD M. COWLING

En este artículo se discute un nuevo enfoque para la conservación sistemática que elimina algunas de las limitaciones del trabajo anterior en este campo.

La mayoría del desarrollo de los métodos de planificación de la conservación se ha basado en la representación de los patrones de biodiversidad (por ejemplo, tipos de vegetación, registros de especies) en reservas. Generalmente se ha asumido también que la puesta en práctica de las propuestas nuevas reservas es una tarea rápida, de manera que no hace falta considerar cuales de las áreas propuestas deberían ser las primeras en recibir protección. Este supuesto puede estar muy lejos de la realidad, donde la puesta en práctica de una reserva es un proceso gradual en el que la pérdida de biodiversidad durante la aplicación de un sistema de reserva puede poner en compromiso la realización de las metas de representación. Se necesita de una estrategia que localice y diseñe nuevas reservas para promover la conservación de los procesos naturales así como los patrones de biodiversidad y que guíe el programa de las acciones de conservación ante los recursos limitados. Este artículo incluye un marco conceptual y un protocolo de diseño de reserva los que consideran explícitamente los patrones y los procesos naturales. Con la misma importancia, este enfoque descrito asume la puesta en práctica gradual de las nuevas reservas, lo cual asegura las intervenciones a tiempo para asegurar la retención de patrones iremplazables y procesos que sean altamente vulnerables a las amenazas. La región de estudio es el bioma de Succulent Karoo en Sudáfrica, desierto reconocido internacionalmente como área crítica, caracterizada por una excepcional biodiversidad y especies de plantas poco comunes. Este estudio no es teórico –identificará las mayores prioridades de conservación en la región y guiará la asignación de los fondos disponibles para estas áreas.

Selección sistemática de reservas en EE.UU.: ejemplo de la ecoregión de Columbia Plateau

FRANK W. DAVIS, DAVID M. STOMS AND SANDY ANDELMAN

Se describe una aproximación a la planificación de la conservación para identificar un conjunto de áreas con unos objetivos específicos para representación biótica teniendo en cuenta que exista un balance entre los objetivos duales de eficacia (área mínima) e idoneidad del lugar. Este enfoque ha sido aplicado por 'The Nature Conservancy' (TNC) en un ejercicio de planificación regional de la ecoregión de la meseta de Columbia en el Noroeste de los Estados Unidos. Esta aplicación requería de la integración de datos de especies, comunidades de plantas, dueños de tierras y otros factores socioeconómicos así como la combinada opinión basada en modelización asistida por ordenador para la selección de lugar. El conjunto de áreas seleccionadas cumplía los requisitos del TNC, sirviendo en la actualidad de anteproyecto en los esfuerzos de conservación de la región. La fuerza de este enfoque viene dada por su flexibilidad y ser bastante explícita, así como por la consideración tanto de objetivos biológicos como de preocupaciones socioeconómicas. Sin embargo, el modelo actual de selección de lugar requiere de un sofisticado sistema de computasióse, tauto de hardware como software, lo cual limita su movilidad y uso por no-especialistas. En el momento trabajamos para mejorar la movilidad y para añadir nuevas funciones para tener en cuenta la prioridad de áreas y la viabilidad de las especies.

Aplicaciones del análisis de la no-reemplazabilidad a los problemas de planificación y gestión

R.L. (BOB) PRESSEY

Uno de los resultados de la investigación y desarrollo en planificación de la conservación en estos últimos años ha sido la idea de no-reemplazar. No-reemplazar se refiere a la importancia de un área (por ejemplo una granja, zona limítrofe o fragmento del bosque) para lograr la conservación explícita de una región, país o un área protegida singular. Un mapa de no-reemplazabilidad es un mapa de opciones para conseguir algunos resultados deseados en la planificación de nuevas áreas protegidas o gestión de las existentes. Para algunas áreas no hay reemplazamiento posible –no se puede conseguir el objetivo sin ellas. Para otras áreas, sin embargo, hay diferentes re-emplazamientos posibles.

Esta información permite a gestores y planificadores el buscar nuevas alternativas para lograr sus objetivos, permitiéndose por tanto la negociación entre diferentes grupos de interés sobre cómo debería conseguirse un objetivo en conservación o gestión. Otra aplicación de la no-reemplazabilidad es la de establecer una serie de prioridades de conservación indicando cómo de fácil sería rehacer las acciones de conservación o zonamiento gestor si una zona particular no estuviese disponible o sus valores naturales estuviesen diezmados. Este artículo resume las ideas y resultados de unos siete años de trabajo en no-reemplazabilidad, así como ilustra dos recientes aplicaciones de la idea en partes del Nuevo Sur de Gales, Australia, y discute sus usos potenciales futuros en la planificación de la conservación y la gestión de las áreas protegidas.

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