The ConsNet Portal 1.0

Systematic Conservation Planning Primer

Land Use Change and Biodiversity Loss. Forest clearing for gardens. Diodio Village, south-west Goodenough Island (Moratua), Papua New Guinea. Habitats are threatened by land use changes in most areas of the world. © 2006 David Mitchell.

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M9: Vulnerability and Persistence Analysis

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Learning Objectives: This module describes how to incorporate persistence and vulnerability into systematic conservation planning. Learners will conceptualize the importance of persistence and vulnerability with new examples as well as some used in previous modules.

- Persistence of biodiversity is the most general goal of conservation.
    - Representation of biodiversity surrogates in a conservation area network is useless if the prognosis for their survival is not good.
    - Planning for persistence requires data and ideas from many different fields.
        - Biology: ecology, evolution, and physiology are all important.
        - Socioeconomic studies must be used to assess non-biological threats to biota.
        - This knowledge must be integrated into plans in such a way that the goal of economy (conservation with least possible cost) is achieved to the extent possible.
    - Planning for persistence remains poorly understood and a topic of ongoing research.

- Both ecological and sociopolitical factors that may influence the persistence of biodiversity need to be incorporated in planning for persistence.
    - Ecological factors are critical for the persistence of species and populations.
    - Three methods are commonly used to incorporate these into planning.
        - Spatial design criteria (see **M6: Conservation Targets and Goals**, and below) are often used because they seem intuitively biologically plausible.
        - Attention should be paid to biological processes that are important for

        biodiversity persistence.
        - Population Viability Analysis (PVA) is useful in some contexts.
    - Sociopolitical factors can be dealt with either using educated intuitions about threats or formal risk analysis.
        - Threats can be minimized by placing conservation areas far from human population centers, extractive activities, roads, and other travel pathways (e.g., rivers).
        - Formal risk analysis can be used when risks and threats can be quantified.

- Ecological design criteria.
    - **Size**: the larger the size, the better it is see **Example 9.1**.
        - However, is this the best use of resources? If a smaller conservation area is adequate for persistence, it may be more reasonable not to expand conservation areas unnecessarily.
        - There was a long debate in conservation planning in the 1970s and 1980s over Single Large or Several Small conservation areas. The current consensus is that there is no general answer to this question.
    - **Shape**: in most circumstances compact shapes are supposed to be better.
        - Empirical evidence for this intuitively plausible rule is lacking so it should be used with caution.
        - In some cases, natural features of the landscape that are relevant for conservation, such as watersheds, may not be compact in shape. If such features comprise the planning units for a conservation planning exercise, it may not be appropriate to maximize compactness.
    - **Connectivity**: connectivity is better because it allows populations to exchange genes, giving a larger **effective population size**. Connectivity also provides escape routes during times of stress (fires, etc., which are examples of environmental stochasticity) see **Example 9.2**.
        - Corridors (narrow strips of intact habitats between existing conservation areas) are one way to establish connectivity.
        - Corridors should be designed so that species will actually use them. For example, planners should base the length and width of the corridors on the dispersal behavior of the species. No corridor should be longer than the maximum known dispersal distance for the species. After the corridors are established, the extent of their use should be estimated by

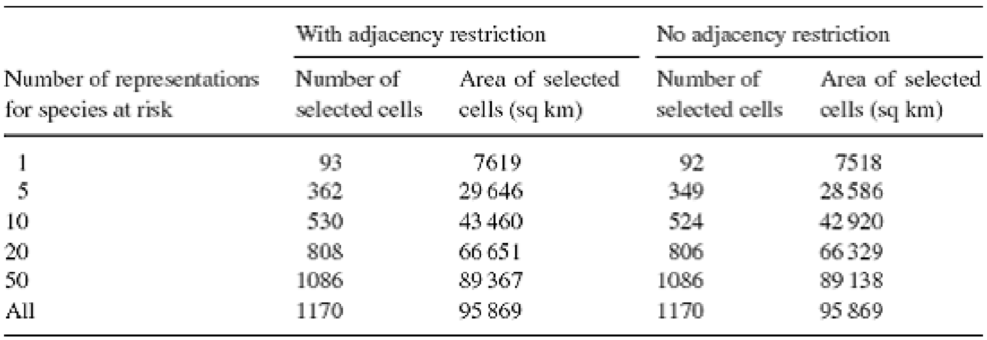
    - mark-recapture experiments.
    - Connectivity may do harm by helping the spread of disease across the landscape.
- **Dispersion**: distributing conservation areas across the entire landscape has two advantages: (i) it helps representation of species including those that may not have been explicit surrogates during area selection; and (ii) it reduces the chance that a single event such as a fire or major disease outbreak will completely eliminate a species.
    - If dispersion means putting conservation areas close to sources of threat (human population centers, extractive activities, roads, etc.) then it may not be desirable.
    - No plan so far seems to have explicitly implemented dispersion.

Example 9.1

Using Adjacency to Increase Conservation Area Size in Québec(Sarakinos et al. 2001)

A conservation area network devised by the provincial government of Québec was found to be largely derived from *ad hoc* decision making such that the representation of biodiversity was not used as a criterion in planning. Sarakinos et al. (2001) found that 75 % of the existing protected regions in Québec were in the northern forest regions. These conservation areas were unsuitable for the representation and persistence of biodiversity. Sarakinos et al. (2001) chose species, mainly species at risk, as surrogates for biodiversity as part of a conservation planning exercise in which areas were prioritized based on rarity and complementarity. Areas were first selected by rarity. If more than one cell was selected in the iterative process, the tie was broken by the cell highest in complementarity. Further ties were broken by adjacency.

Table 9.1a
Québec
The size of Québec is 1 522 842 sq km. This table shows the areas of cells selected in Sarakinos et al.'s (2001) analysis.



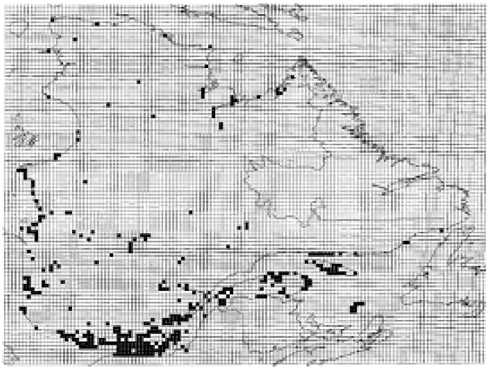
	With adjacency restriction		No adjacency restriction	
Number of representations for species at risk	Number of selected cells	Area of selected cells (sq km)	Number of selected cells	Area of selected cells (sq km)
1	93	7619	92	7518
5	362	29 646	349	28 586
10	530	43 460	524	42 920
20	808	66 651	806	66 329
50	1086	89 367	1086	89 138
All	1170	95 869	1170	95 869

From Sarakinos et al. (2001)

Figure 9.1

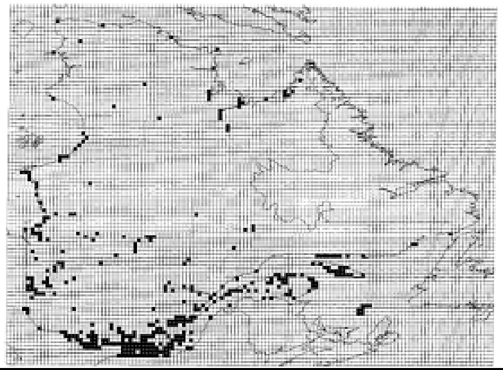
(a)

Selected Cells with 10 Representations of Species at Risk using the Adjacency Rule (Sakarinos et al. 2000).



(b)

Selected Cells with 10 Representations of Species at Risk Not using the Adjacency Rule (Sakarinos et al. 2000).

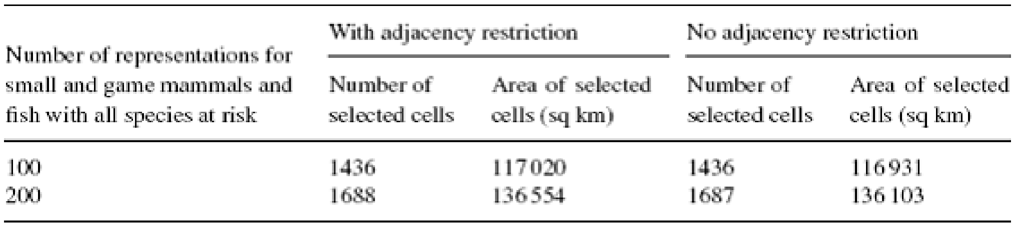


From Table 9.1a and Figures 9.1a, b, it is evident that the results obtained using the adjacency rule and without the adjacency rule are extremely similar. Thus, simply selecting areas on the basis of adjacency after using rarity and complementarity did not result in conservation areas that were significantly more compact .

In Tables 9.1b, small and game mammals and fish have been added to all species at risk for the entire region of Québec and selection for adjacency is again found to play an insignificant role in the representation of species.

Table 9.1b

The Entire Province of Québec



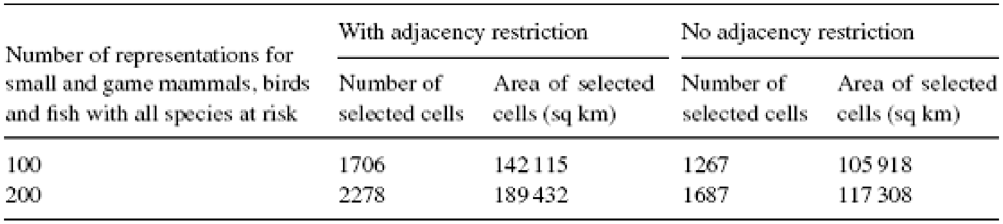
Number of representations for small and game mammals and fish with all species at risk	With adjacency restriction		No adjacency restriction	
	Number of selected cells	Area of selected cells (sq km)	Number of selected cells	Area of selected cells (sq km)
100	1436	117 020	1436	116 931
200	1688	136 554	1687	136 103

From Sarakinos et al. (2001)

However, in Table 9.1c, the adjacency rule does play a significant role in the total area of the selected cells. (The data in the Table are for southern Québec. This is due to the inclusion of birds as surrogates.

Table 9.1c

Southern Québec



Number of representations for small and game mammals, birds and fish with all species at risk	With adjacency restriction		No adjacency restriction	
	Number of selected cells	Area of selected cells (sq km)	Number of selected cells	Area of selected cells (sq km)
100	1706	142 115	1267	105 918
200	2278	189 432	1687	117 308

Specifically, Sarakinos et al. (2000) suggested that because most of the existing conservation areas were in northern Québec, the southern areas were needed for representativeness. However, because southern Québec has more urban areas than northern Québec, conservation planning for southern Québec must incorporate socio-economic factors more extensively than planning for the northern part of the province.

Example 9.2

Establishing Connectivity in the Transvolcanic Belt of Mexico (Fuller et al. 2006)

The interdigitation of the Neararctic and Neotropical biogeographic zones in the Transvolcanic Belt (TVB) of central Mexico provides the region with high faunal richness and **endemicity**. Biodiversity conservation in the TVB must accommodate the region's human population of more than 40 million. Fuller et al. (2006) developed conservation plans for the TVB intended to protect 99 non-volant terrestrial mammal species while minimizing the impact on the human population. A rarity-complementarity algorithm was used to select a conservation area network from areas with untransformed vegetation to represent 10% of each species' habitat. In addition, a new method was developed for augmenting the connectivity of conservation area networks using graph theory. This study made the following assumptions: (1) The 99 non-volant mammal species are adequate surrogates for biodiversity. (2) Species distributions can be assessed with sufficient accuracy using niche modeling (they used GARP)-see **M4: Data Compilation, Assessment, and Treatment**. (3) The connectivity areas selected using graph algorithms would be suitable as dispersal corridors or migratory routes for non-volant mammals.

The TVB was divided into 106 026 sites at a 0.01° × 0.01° resolution of longitude x latitude. Individual areas varied between 1.153 km.^{2} and 1.179 km.^{2}, with an average of 1.163 km.^{2} Figure 9.2a shows the study region. They used the ResNet software package to select conservation areas and the LQGraph software package to establish connectivity between the conservation areas (Figure 9.2b).

Figure 9.2a

Transvolcanic Belt of Central Mexico

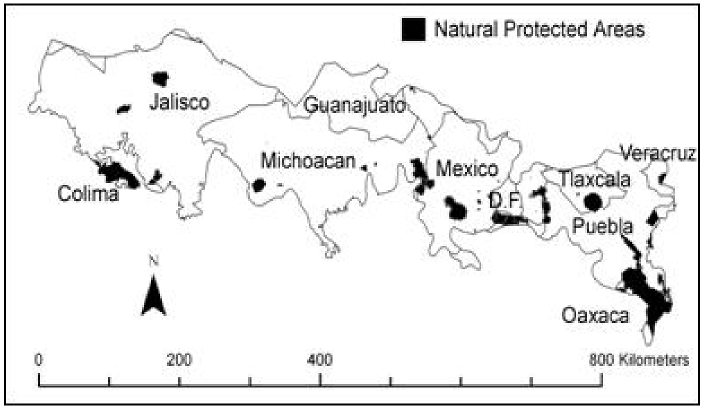
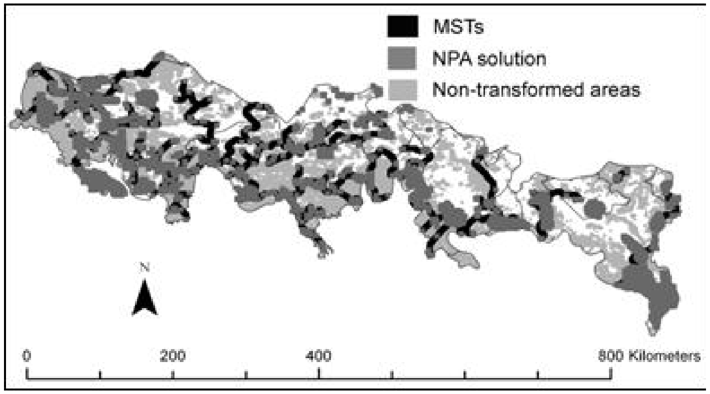


Figure 9.2b

Connectivity Establishment Among Conservation Areas in Central Mexico

"NPA solution" refers to the areas selected by ResNet to represent 10 % of the habitat of 99 non-volant mammals. The place-prioritization was initialized with the existing natural protected areas of the region (NPAs). "Non-transformed areas" are those areas with intact primary or secondary vegetation. The graph algorithms selected non-transformed sites to link the conservation areas. The connectivity-conferring areas were selected using an algorithm for finding minimum spanning trees ("MSTs")



- Biological processes: ecological and evolutionary processes are critical to the persistence of biodiversity and should be accommodated in conservation area networks. Seven sets of ideas guide incorporation of processes into planning (Margules and Pressey 2000)-see **Example 9.3**.
    - **Biogeographical theory**: a conservation area network should consist of large circular reserves that are close together and linked by corridors (Diamond & May 1976; Harris 1984).
        - Caution must be exercised in applying equilibrium island biogeography theory to terrestrial conservation areas-there is little evidence supporting the analogy between oceanic islands and terrestrial reserves (Margules et al. 1982)
        - Corridors inherit the problems with connectivity mentioned above.
    - **Metapopulation dynamics**: many species are distributed across landscapes as metapopulations (Hanski 1998). Prioritization should include areas establishing connectivity between local populations to facilitate migration and minimize local extinctions - often a characteristic of metapopulations (van Langevelde et al. 2002).
    - **Successional pathways**: different successional stages corresponding to taxa habitat requirements should be included in a conservation area network.
        - Large conservation areas are better at meeting this objective since they are less likely to be entirely reset to the early seral stages (successional stage of that community) by a single event such as a fire.

- **Spatial autoecological requirements**: a conservation area network should represent at least a minimum viable population for each species (see below for more on viability assessment).
  - Species such as altitudinal migrants have particular requirements for the configuration of conservation areas which must be accommodated.
  - Some species require several habitat types in each conservation area.
- **Source-sink population structures**: when species have a source-sink population structure, the **source habitats** must be assigned high priority for conservation.
- **Effects of habitat modification**: conservation areas in fragmented landscapes require special management.
  - Habitat restoration may be necessary to safeguard many species in such fragmented landscapes.
  - Addition of new habitat between and along the perimeters of fragments is usually desirable to minimize edge effects.
  - Connectivity is similarly important in such landscapes
- **Species as evolutionary units**: prioritization should give preferences to sites with physical properties thought to encourage speciation.
  - Such habitats include interfaces between soil types.
  - Areas containing taxonomically distinct species or species with radiating phylogenies should also be targeted.

Example 9.3

Incorporating Processes into Design in the Cape Floristic Region of South Africa (Pressey et al. 2003)

The Cape Floristic Region of South Africa is region known for high plant endemism and is thus a global biodiversity hotspot. In the late 1990s a systematic conservation plan was devised called the Cape Action Plan for the Environment or CAPE . Besides setting representation targets for biodiversity surrogates, Pressey et al. (2003) also incorporated biodiversity and anthropogenic (human-related) processes into the systematic conservation planning of the Cape Floristic Region. The group used four approaches for the incorporation of biodiversity processes: (i) inclusion of biodiversity patterns related to small-scale biological processes, such as plant-pollinator interactions and population processes of smaller sized animals; (ii) consideration of common design criteria parameters, such as preference for specific shape, size, and connectivity; (iii) inclusion of persistence of specific processes, such as specific disturbance regimes or migration patterns; and (iv) inclusion of spatial patterns related to processes, such as climatic zones and ecotones.

The first type of process (i), taking into account small-scale biodiversity patterns, is an important aspect of conservation planning. Small-scale processes are important and can include elements of larger scale patterns, but they still do not incorporate all population and ecological processes. Common design criteria parameters (ii) are useful in the sense that they may encompass biodiversity processes and disturbance regimes; however, they represent processes at a coarse scale. Persistence of specific processes (iii) is important because they account for natural disturbances, viable population sizes, spatial requirements, habitat quality, and species' utilization of different habitats and landscapes. Finally, spatial patterns and related processes (iv) are important in systematic conservation planning because the conservation areas should include regions of specific physical and climatic characteristics and ecotones required for the persistence of the biodiversity surrogates. It is important to realize that each of these biodiversity processes is different, and while one type of process may include aspects of another, they do not encompass each other, and therefore all must be incorporated into systematic conservation planning for a region. In the planning exercise for the Cape Floristic Region, all four approaches were used.

The types of processes that Pressey et al. (2003) propose are important in setting conservation goals during systematic conservation planning. This broadened view of setting goals (beyond representation of surrogates) tries to use information on how the inclusion of different land types influence the persistence of biodiversity. An advantage of planning for processes is that it does not require species-specific data, which are rarely available. Instead, planning for processes typically requires data on land types, which can often be obtained via remote sensing.

- Population Viability Analysis (PVA) tries to predict the fate of a population by estimating parameters such as the expected time to extinction, or the probability of extinction within a given time period (e.g., 100 years).
    - Uses ecological theory and modeling to predict the future fate of a population.
    - Takes very different forms depending on whether large populations or small populations are being studied.
        - For large populations, the intrinsic growth rate shows where the population is heading.
        - If the intrinsic growth rate is negative, the population is on its way to extinction.
        - However, small populations may become extinct due to chance factors (stochasticity) even if the intrinsic growth rate is positive
    - Carrying out PVA requires a lot of data, at the very least, population sizes for

many years (demographic data)-see **Example 9.4**.

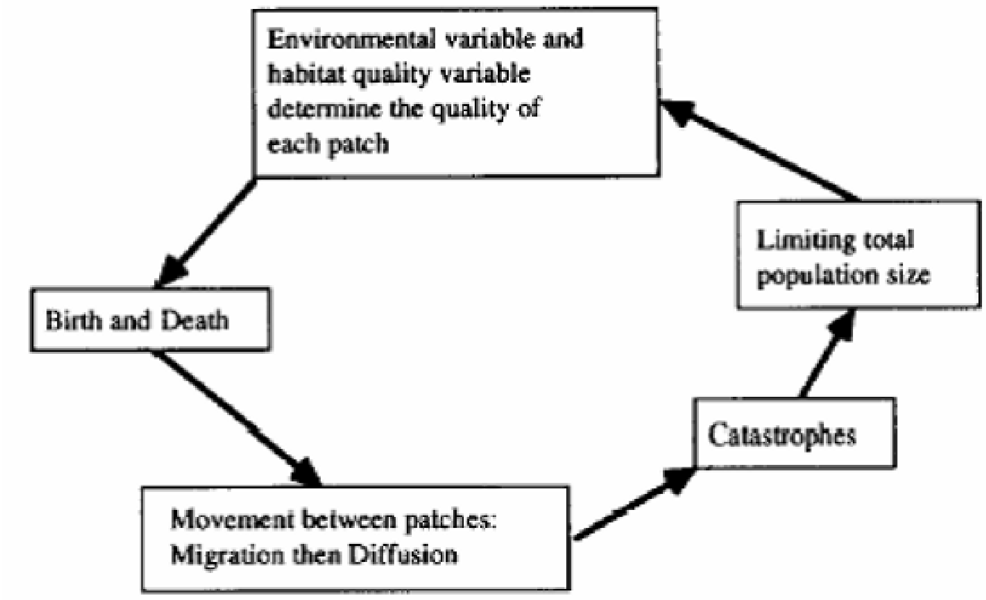
Example 9.4

Population Viability Analysis of Leadbeater's Possum (*Gymnobelideus leadbeateri*) in Victoria, Australia (Lindenmayer and Possingham 1996)

Leadbeater's possum is a nocturnal marsupial endemic to mountain ash trees in the Central Highlands of Victoria, Australia. Due to fires in 1939, Leadbeater's possum lost 70 % of its nesting habitat. In the 1980s and 1990s, possum nesting sites were declining at a rate of 4 % a year due to logging practices. Lindenmayer and Possingham (1996) decided to evaluate different forest management practices and their effects on the survival and persistence of the possum . They evaluated the metapopulation structure of the possum and the quantity and spatial arrangement of forest patches that serve as possum habitat. Only the female possums were modeled because they are the limiting factor for the size of the metapopulation. Females were assigned to three age classes; environmental variation, demographic stochasticity, and migration were also included in the model.

Figure 9.4a

Relational Map of Leadbeater's Possum Metapopulation Characteristics and Influences

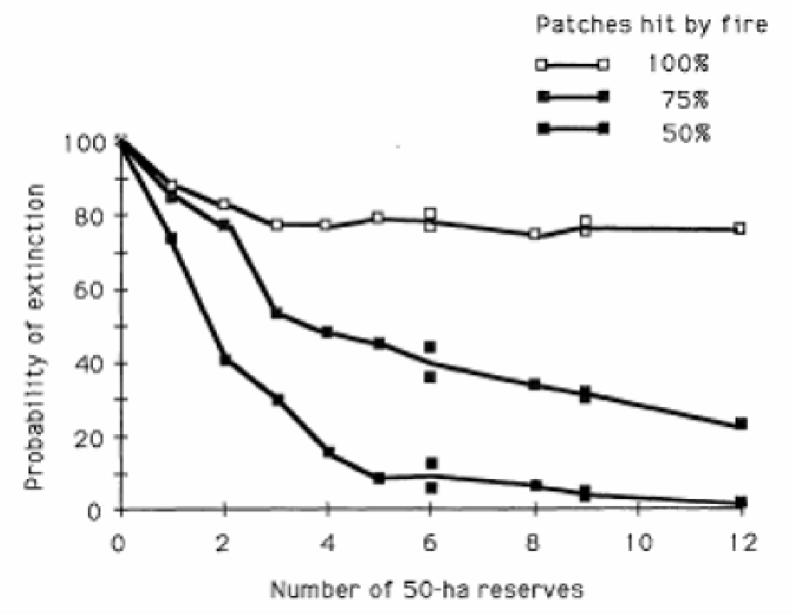


From Possingham and Davies (1995).

Five different scenarios were evaluated. Scenario 1 assumed that current logging practices do not change and that wild fires destroy 50% to 70 % of the forest nest site patches. The next two scenarios built upon Scenario 1 but included (2) a 300 hectare forest patch set aside for conservation and (3) 12 conservation areas 24 hectares in size. The last two scenarios built upon Scenario 1 but included 20 conservation areas 50 hectares in size. The results of the simulations indicated that reducing logging would increase the probability that the possum metapopulation would survive. Of the five scenarios, the last two, which included the cessation of logging practices and inclusion of more forest sites of a size of 50 hectares or larger, seemed to be the best management strategies. Having fewer sites of larger size did not contribute to the viability of the Leadbeater's possum due to the metapopulation structure and the incidence of forest fires. The results of the model indicate that species with a metapopulation structure need more sites of variable size to persist. This results seems plausible in light of the life history of the possum.

Figure 9.4b

The Probability of Metapopulation Extinction as a Function of the Number of Conservation Areas.



From Lindenmayer and Possingham (1996).

- There are several limitations of PVA which often makes it impossible to use in a practical context.
  - So far PVA methods are restricted to a single species or to very few species at a time.
    - When hundreds of species are used as surrogates, they must all have their viabilities assessed. In practice this is impossible.
  - PVA requires a huge amount of demographic or other data.
    - Such data are available for very few species, probably less than a few hundred species in the whole world.
    - The data require many years of fieldwork. Typically, conservation plans can't wait for all such data to be gathered.
  - Slightly different models used in PVA give very different results. This is known as structural uncertainty (or model uncertainty) and makes PVA difficult to trust in the practical realm.
  - The most valid use of PVA may be for endangered species which are being closely monitored (for instance, species listed in the Endangered Species Act in the United States).
- Sociopolitical factors are relevant to what happens to any piece of land and must, therefore, be taken into account during planning.
  - In the tropics, it is well known that deforestation follows roads. So it makes sense to place conservation areas as far from roads as possible.
  - Large human population centers almost always represent serious threats to species.
  - Extractive activities such as mining and drilling affect habitats directly and indirectly (through pollution downstream or downwind, the construction of roads, pipelines, etc.).
- Multicriteria analysis (MCA) is typically used to incorporate sociopolitical criteria into conservation area network design - see **M11: Multiple Criteria Analysis**.
  - MCA is typically used to decide between different conservation area networks which all satisfy the biodiversity representation targets.
  - However, some obvious external threats can be taken into account at the stage of selecting areas (see **M8: Place Prioritization**) and then the proposed network can be refined - see **M10: Network Refinement Protocol**.

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M14: Conclusion and Review - Future Directions

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