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10 -? 18 required the protection of 80 ha, increasing the number
Mintmum number of
species represented

5 10 15 20 25 30
Number of towns with access

Fig. 2. Cost (expressed in ha protected) of increasing the number of towns with access to protected sites under different requirements for the number of species represented. A town had access if it had at least two
r protected sites within 3 km.

3. Results

In the base case, we maximized the number of towns
with access to protected sites assuming that 17 of the 68 sites were already protected. A town had access if at least two sites were protected within an average travel distance of
3 km of the town. For simplicity, we assumed that the cost per unit area was the same in each site and therefore the cost of protecting a site was equal to its area. To estimate a cost curve, we solved the optimization model using upper bounds on the budget from 0 to 1000 ha. The lower bound on the number of species was 55, which was the number of species represented in the 17 already-protected sites. Under these base-case assumptions, the slope of the cost curve was flat initially and then increased rapidly (Fig. 2), indicating that incremental increases in the number of towns with access required purchasing larger numbers of sites and amounts of land. When the budget was zero, nine towns had at least two already-protected sites within the 3 km distance standard. While increasing the number of towns with access from 9 to

of towns with access frorn 18 to 26 required protecting an additional 650 ha.
To investigate the tradeoff between site accessibility and species representation, we computed cost curves with rep-resentation constraints of 60 and 61 species. Increasing the representation constraint frorn 55 to 6 1 species did not affect the shapes of the cost curves but moved them up (Fig. 2). The horizontal distance between points on the cost curves shows the tradeoff for a given budget. For example, with a budget of 200 ha, increasing the representation requirement from 55 to 60 species means that eight fewer towns have ac-cess to protected sites. In our Lake County data, six species are not represented in the 17 already-protected sites, and they are present in a small number of unprotected sites. As a result, requiring representation of more than 55 species restricts the number of sites that can be picked and reduces the number of towns that can have access to protected sites under a given budget. The maps in Fig. 3 demonstrate this tradeoff. With a representation requirement of 55 species, 12 new sites covering 200 ha are protected so that 22 towns have access to reserves. With a representation requirement of 60 species, four new sites covering 199 ha are protected so that 14 towns have access to reserves.
The vertical distance between points on the cost curves shows the additional area required to protect increasing num-bers of species (Fig. 2). For example, if 24 towns are required to have access to reserves, increasing the species coverage requirement from 55 to 60 requires approximately 160 ha of

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base case while maintaining the level of species representa-
tion? The cost of the 17 protected sites in terms of area was
5757ha. After adjusting the budget to 5757 ha, designating
the protected sites as unprotected, and requiring the same
level of species representation (55). we found a set of 27
sites that provided access to 26 towns, an improvement in accessibility of 17 towns compared with the base case. The 27 sites were smaller and more uniformly distributed over the study area. To see what could be accomplished in terms of species representation, we increased the representation requirement to 61 species and found a set of 24 sites that provided access to 23 towns. As a result, if we assumed that none of the 68 natural areas were protected and we had a budget to protect 5757 ha, we could acquire a set of 24 sites that provided more access and represented more species than the set of 1'7 currently protected sites.
To investigate the impacts of changing the definition of ac-cessibility, we computed cost curves with different distance standards for comparison with the base case. The distance standard affected the location and slope of the cost curve

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10 1 M~nfmum number of srtes

g 4 within 3 km d~stance
8 4 standard
'is 7 -51
0 6 +2
z 5 +3

0 5 10 15 20 25 30 35
Number of towns with access

lem and need not always be the case. In our application, most of the species were represented in already-protected sites.
Because the remaining species were present in a small num-
ber of unprotected sites, there was little flexibility in choos-
ing sites to represent all of the species. In addition, those
sites were located far from towns that did not have access
to already-protected sites. As a result. when the budget was
limiting, a requirement for were prese2/j -0.025 Tc 0278 Tc 9 0 0 8.625 120.0

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is required to investigate how these model extensions and needed to integrate the results from those single-species con-
increases in model size affect computational requirements. servation models into multi-objective site selection models
We found that the set of already-protected sites was not like the one presented here.
as eflecthe in terms of accessibility and species representa- While site selection decisions are often made within po-
tion as efficient sets of sites found by the model. While this litical boundaries such as a county, species and ecosystem
analysis showed how

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