



32

TRIAGE: PRIORITIZING SPECIES AND HABITATS

In collaboration with Jon Conrad

Objectives

- Develop a prioritization scheme for species conservation.
- Develop habitat suitability indexes for parcels of habitat.
- Set up a spreadsheet model that combines habitat conservation priorities with a habitat acquisition budget.
- Use a spreadsheet optimization program to determine which habitats should be purchased to optimize species conservation given a budget constraint.

INTRODUCTION

Conserving biodiversity requires a series of complex decisions. Like it or not, often our decisions for protecting species are governed by the funds available. With a limited budget and an array of habitats to choose from, which parcels should be purchased to best achieve conservation goals? In practice, there are many factors involved. Much like triage in a medical emergency situation, we must make hard decisions about which “patients” can be saved, which are most urgently in need of immediate help, and which will survive even without our immediate intervention. Among the key issues that must be addressed are:

- Not all species have equal conservation value. Species that are globally rare, endangered, or play critical roles in ecosystem function (“keystone” species) may be deemed more “important” for a conservation effort than other species.
- Not all habitats are of equal value. Some habitats, if acquired for conservation purposes, will promote conservation objectives more effectively than others. Hence, conservation biologists need to know something about the suitability of various habitat parcels and the nature of patchiness and landscape ecology.
- Conservation does not occur within a vacuum. It requires interaction with the social and political arenas of a given region, and getting anything done usually requires compromise.

The goal of this exercise is to introduce you to three important concepts in the practice of making conservation decisions: prioritization schemes, habitat suitability indices, and optimization models. We will discuss each, then put them together into a modeling framework to determine how habitat purchases can be

made for conservation purposes. This exercise works well if you collect actual data from your area to use in the model.

Prioritization Schemes

Let’s assume you have been asked to identify the plant species in your area that are of highest conservation concern. How will you go about distinguishing between those species that are of immediate concern, those that are not currently in jeopardy but may become endangered, and those that appear to face no danger? One approach is to develop a species **prioritization scheme** (Hunter 1996). Your prioritization scheme will center on those criteria that you deem important for conservation. For example, if you think species with few individuals merit more conservation effort than abundant species, your criterion is “population size.” In this case, the species with few individuals will score higher than an abundant species. Similarly, if you think that species that are declining in numbers are of more concern than species whose numbers are stable, your conservation criterion is “population trend.”

Suppose you are faced with a species that is locally very rare, but globally abundant; the criterion is “local abundance.” How should you score such a species? You might give it a high ranking if the species garners a lot of support from the community, or if protecting that species in your area means several other species will be protected as well. However, because the species is globally abundant, you may decide to use limited conservation dollars on another species that is rare everywhere (Hunter and Hutchinson 1994).

As a conservation biologist, you determine which criteria are most important for evaluation, and should be able to justify your choices. Ideally, your criteria will be *independent* of each other, so that if you know the score for one criterion, you don’t necessarily know the score for another criterion. In this exercise, we will use “global abundance,” “population threats,” and “population trend” as conservation criteria. In reality, you probably would examine more than these three criteria. In scoring your species, you might use a scale of 1 to 5 as potential scores, where 5 indicates the highest conservation priority and 1 indicates the lowest. Ideally, you would have at your disposal data that will help you assign scores objectively. For example, long-term survey data will help you to determine whether the population trend is sharply declining (the species receives a score of 4 or 5), stable (score 3), or increasing (score 1 or 2).

Figure 1 shows a hypothetical prioritization scheme for three species. Species 1 is very abundant, its populations are not currently threatened in any measurable way, and its population trend is stable. So it scores 1 each for global abundance and population threats, and 3 for population trend. In contrast, species 3 is globally very rare, with significant population threats because its range and total population size are so small. This species receives a 5 for global abundance and population threats. Although species 3’s population size is small, its population trend is currently stable, so it receives a 3 for population trend.

	A	B	C	D	E
3	Species Prioritization Scheme				
4					
5			Species 1	Species 2	Species 3
6	Global abundance =>		1	3	5
7	Population threats =>		1	3	5
8	Population trend =>		3	4	3
9					
10	Score =>		5	10	13

Figure 1 Prioritization scores in three criteria (abundance, threats, and population trend) for three hypothetical species. The scores are summed to show which species is of highest concern when all criteria are considered. In this case, species 3 is of highest immediate conservation concern, followed by species 2 and 1.

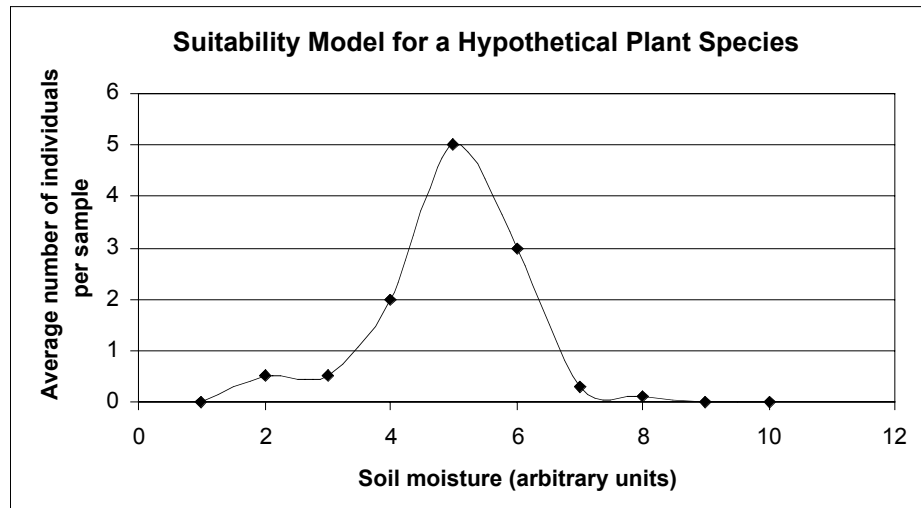


Figure 2 For the range of conditions sampled, it appears that this plant species requires intermediate levels of moisture.

Habitat Suitability Models

After you have prioritized the species in terms of its conservation value, you will develop a **habitat suitability model**. A suitability model suggests which habitat conditions are required for a species to occur (presence or absence), that are required to host high densities of individuals, or that are required in order for the species to remain viable for a given number of years. See Exercise 28, "Population Viability Analysis." How can you determine which habitats are the "best" for a given species? The most obvious way is to go out into a variety of habitats and measure some feature that you think is associated with "suitability." For example, Figure 2 shows the average number of individuals per sample plot for a particular species as a function of soil moisture.

Another kind of suitability model simply compares the occurrence or density of individuals across different sites. In this case, you may not know *why* one site appears to be more suitable than another, only that currently the sites vary in the number of individuals that occupy them. Figure 3 shows the occurrence of a plant species in 100 samples in 5 different sites. Suitability scores are often standardized so that they range from

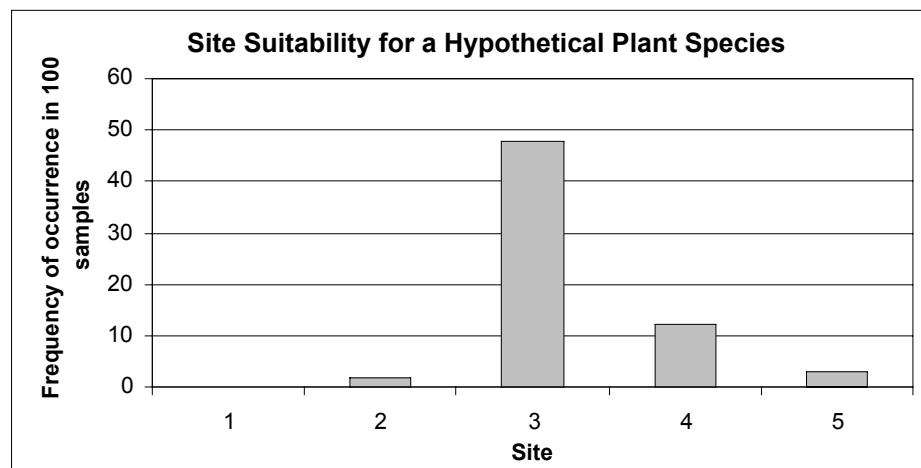


Figure 3 The species of interest was present in 48 of 100 samples in site 3, which thus appears to be more suitable than the other four sites for this particular species.

0 (unsuitable) to 1 (suitable). We will do a simple standardization of scores in the exercise. The real value of knowing habitat suitabilities is that you can apply this information to making wise decisions about conserving species, which we will do with an optimization procedure.

Optimization Models

The final step in prioritization is to use an **optimization model** to determine which habitats should be purchased, given the priority species and their habitat suitability models. In the exercise, you will be given a fixed budget and will be asked which of four sites should be purchased to maximize conservation efforts for five species. We'll assume that you have a fixed budget (\$1,000,000) and that you also have information on the probability of development of each site, which gives the risk of losing all the habitat in a particular parcel. Given this information, and knowing the priority species and the suitability of each site for the various species, which sites should you purchase to maximize conservation efforts? You may be able to purchase one, two, three, or all four sites, depending on the conditions in your model.

Most spreadsheets run a program that can find an “optimal” or “best” solution to a problem, given a number of things that must be considered in the quest. These optimization functions run through a variety of different scenarios and calculate the outcome for each scenario. The optimization program we use is called **Solver**. There are many different kinds of optimization models, but Solver will be sufficient for our needs in this exercise.

PROCEDURES

In our exercise, then, we must decide which of four sites should be purchased, given the “value” of the different combinations of sites. We want to determine the overall “conservation value” when site 1 is purchased alone, when site 2 is purchased alone, when site 3 is purchased alone, when site 4 is purchased alone, when sites 1 and 2 are purchased, when sites 1 and 3 are purchased, and so on until all combinations are examined. This “conservation value” is based on how suitable the habitat is for each of the five different species, the cost of acquiring the habitat for conservation, and well as the probability that a site will be developed if it is not acquired for conservation purposes.

Once you have set up your spreadsheet, you can explore how various factors influence the “optimal” choice. As always, save your work frequently to disk.

INSTRUCTIONS

A. Establish a prioritization scheme.

1. Open a new spreadsheet and enter column headings as shown in Figure 4 on facing page.
2. Enter the values shown in cells C6–G8.
3. In cells C10–G10, use the **SUM** function to obtain a total score for each species.

ANNOTATION

We entered “global abundance,” “population threats,” and “population trend” as conservation criteria. In reality, you probably would want to examine more than three criteria.

We have entered hypothetical data from 1 to 5 for five species in cells C6–G8, where 1 indicates low priority and 5 indicates the highest conservation priority.

Enter the formula **=SUM(C6:C8)** in cell C10. Copy the formula across to cell G10. Because each criterion can have a maximum score of 5 and a minimum score of 1, the total scores will range from 3 to 15, where large numbers indicate species of high conservation priority and low numbers indicate species of low priority.

	A	B	C	D	E	F	G
1	Triage: Prioritizing Species and Habitats						
2							
3	Species Prioritization Scheme						
4							
5			Species 1	Species 2	Species 3	Species 4	Species 5
6	Global abundance =>		1	3	1	4	3
7	Population threats =>		1	3	2	5	5
8	Population trend =>		3	4	3	4	5
9							
10	Score =>						

Figure 4

4. Save your work.

B. Develop a habitat suitability model.

1. Set up new spreadsheet headings as shown in Figure 5.

Next, determine the most suitable habitat for each species. We'll assume you have habitat data from four different sites. Site 1 is a low elevation site that is 5 hectares in size. Cells B18–C20 describe the characteristics of the remaining sites.

	A	B	C	D	E	F	G	H
13	Habitat suitability models							
14				Density				
15		Patch	Elevation	Species 1	Species 2	Species 3	Species 4	Species 5
16		size (ha)	(meters)					
17	Site 1	5	14	3	0	0	0	0
18	Site 2	10	30	2	3	0	0	2
19	Site 3	50	90	0	0	2	1	0
20	Site 4	100	50	0	0	1	3	2
21			SUM =>					
22	Standardized suitability indices			Species 1	Species 2	Species 3	Species 4	Species 5
23	Site 1							
24	Site 2							
25	Site 3							
26	Site 4							
27								

Figure 5

2. Enter the values shown in cells D17–H20.

We will now assume that you have a limited budget that will allow you to roughly estimate the **average density** of individuals in the four different sites. We assume you based your scores on how many individuals occur per unit area, on average, in samples collected on the site. Here we assume that for species 1, the average density is 3 individuals per sample in site 1, 2 individuals per sample in site 2, and 0 individuals per sample in sites 3 and 4. Based on this information, sites 3 and 4 appear to be unsuitable, site 1 is the most suitable, and site 2 is the second most suitable for species 1.

3. In cells D21–H21, use the **SUM** function to sum the suitability scores across the four sites.

Enter the formula `=SUM(D17:D20)` in cell D21. Copy formula across to cell H21.

4. Calculate a standardized suitability score for site 1, species 1 in cell D23.

Enter the formula `=D17/D21` in cell D23. You need to standardize your values to reflect an overall suitability score. Suitability scores typically range from 0 to 1 and can be calculated in many different ways. Here, we enter the formula above to calculate suitability as the *proportion of the total values occurring in a given site*. Your spreadsheet should return the value 0.6; this is your habitat suitability coefficient for species 1 in site 1.

406 Exercise 32

5. Calculate remaining scores in cells D23–H26.

6. Graph suitabilities of the species for each site.

Enter the formula $=D18/\$D\21 in cell D24 to determine site 2’s suitability for species 1. Enter the formula $=D19/\$D\21 in cell D25 to determine site 3’s suitability for species 1. Enter the formula $=D20/\$D\21 in cell D26 to determine site 4’s suitability for species 1. Enter analogous formulae in cells E23–H26 to determine suitability indices for each site for each species.

Use the line graph option, and select the data series in column option. Label your axes fully. Your graph should resemble Figure 6. Interpret your graph before proceeding.

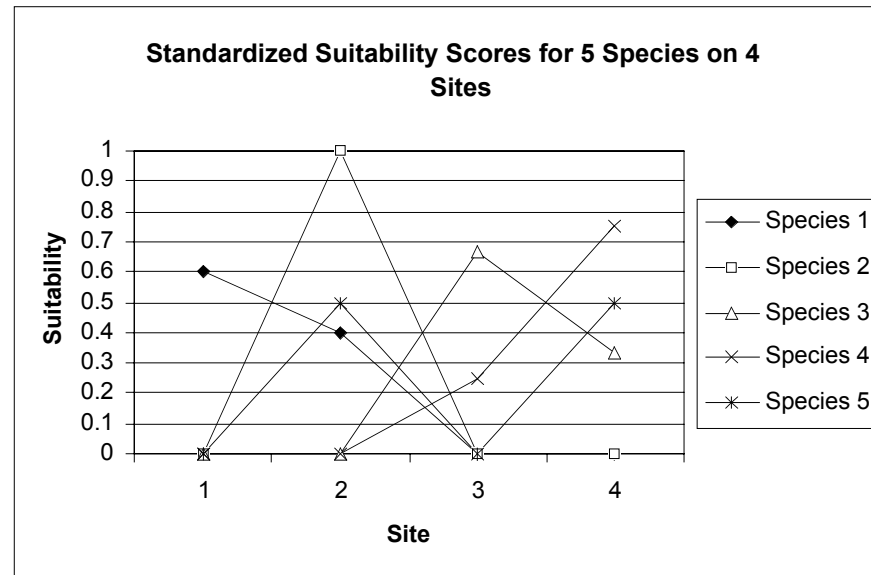


Figure 6

7. Save your work.

C. Develop an economic model.

1. Set up new spreadsheet headings as shown in Figure 7 on facing page.

2. In cells B34–F37, enter formulae that link each cell to your standardized HSI score.

3. In cells B39–F39, enter formulae that link each cell to the species priority scores.

4. Enter the probability of development and costs of achieving each site.

The next step is to incorporate your suitability scores and prioritization schemes into an economic model, so that the “best” sites can be purchased. Cells A30–F55 make up the economic model.

Enter the formula $=ROUND(D23,1)$ in cell B34.

This is simply the suitability score in cell D23 rounded to the first decimal place. Copy this formula across and down to cell F37 to reveal the remaining suitability scores.

Enter the formula $=C10$ in cell B39. Copy this formula across to cell F39.

In rows 42–45, enter the values shown in Figure 7.

Figure 7 provides information on how much each site will cost, as well as the probability of each site’s being developed in the near future, in which case the habitat will be destroyed. If a site has a high probability of being developed and is important habitat for species of high-ranking scores, the site may be a high priority. But perhaps you can wait on purchasing sites for which the probability of development is low, because the sites will likely continue to serve some conservation function.

	A	B	C	D	E	F
30	Optimizing the habitat portfolio					
31						
32	Species identification					
33		Species 1	Species 2	Species 3	Species 4	Species 5
34	Site 1					
35	Site 2					
36	Site 3					
37	Site 4					
38						
39	Priority score					
40						
41	Probability of development			Cost of acquiring site		
42	P1 =>	0.7		C1 =>	500,000	
43	P2 =>	0.4		C2 =>	300,000	
44	P3 =>	0.8		C3 =>	700,000	
45	P4 =>	0.1		C4 =>	1,000,000	
46						
47	Budget =	1,000,000				
48						
49		Choice variables	P*CV*Sum(Score,HSI)			Cost of site
50	Site 1	0				
51	Site 2	0				
52	Site 3	0				
53	Site 4	0				
54						
55	Value of habitat portfolio =>			Total Cost		
56						

Figure 7

For now, site 1 will cost \$500,000 to purchase and has a somewhat high probability of development. Site 4 will cost \$1,000,000 to purchase, but has a low probability of development.

5. Enter 1,000,000 in cell B47.

6. Save your work.

Let's assume that you have a budget of \$1,000,000. Take a good look at all of the data you have at your disposal. You know how much each site costs and its probability of development. From your suitability models, you know which of the four sites are the most valuable for a given species. You also know from your prioritization scheme which species are the most important for conservation efforts. Based on this information, and given a total budget of \$1,000,000, which sites should you purchase, and why?

Using Solver

Now you are ready to use the function **Solver** to mathematically solve your optimization problem. To access Solver, go to Tools | Solver and select Solver. (If Solver does not appear in the menu, go to Tools | Add-ins and select the Solver add-in.) The dialog box shown in Figure 8 of the exercise will appear. In general, Solver works through the following steps:

- In the Set Target Cell box, enter a cell reference or name for the target cell. The target cell must contain a formula. In our exercise, we want to set the target cell as the "total conservation value."
- To have the value of the target cell be as large as possible, click Max. To have the value of the target cell be as small as possible, click Min. To have the target cell be a certain value, click Value of, then type the value in the box. In our exercise, we will select Max to select the maximum conservation value.

TABLE 1. Operators Used as Constraints in Solver

Operator	Meaning
<=	Less than or equal to
>=	Greater than or equal to
=	Equal to
int	Integer (applies only to adjustable cells)
bin	Binary (applies only to adjustable cells)

- In the By Changing Cells box, enter a name or reference for each adjustable cell, separating nonadjacent references with commas. The adjustable cells must be related directly or indirectly to the target cell. In our model, we will let cells that indicate whether a site has been purchased or not be changed. If a site is purchased, it will have the score of 1. If a site is not purchased, it will have a score of 0. Thus, the program will run through all the various scenarios of 0's and 1's as part of the optimization procedure.
- In the Subject to the Constraints box, enter any **constraints** you want to apply. For instance, we will constrain the site purchases so that we do not overspend our total budget. Table 1 lists of the operators that can be used in writing constraints.
- Click Solve. Solver will now run through several different scenarios with varying combinations of sites, evaluating the conservation value of each combination, given the constraints you identify. When the Solver finds a solution (in this case, the maximum conservation value), a dialog box will appear, asking you whether you want to keep the solution or to restore the original values.
- To keep the solution values on the worksheet, click Keep Solver Solution in the Solver Results dialog box. To restore the original data, click Restore Original Values (see Figure 9).

Now we will apply Solver to the data we obtained in Parts A–C.

INSTRUCTIONS

D. Develop an optimization model.

1. Enter 0 in cells B50–B53 (see Figure 7).

2. In cell D50, enter a formula to determine the value of a site when all of the species of interest are considered simultaneously, along with the probability of site development.

3. In cell D55, enter a formula to sum the value of the sites that are actually purchased.

ANNOTATION

Enter the number 0 in cells B50–B53, indicating that you have not yet purchased any of the sites. If a site has not been purchased, it is given a value of 0, and if the site is purchased, it receives a value of 1. Solver will use this binary mode as its Choice Variables.

In cell D50, enter the formula **=B42*B50*(B34*\$B\$39+C34*\$C\$39+D34*\$D\$39+E34*\$E\$39+F34*\$F\$39)**. Copy this formula down to cell D53.

This is the crucial formula for the optimization model to work from. Work through the equation above and make sure you understand its parts. **B42** is the probability a site will be developed. **B50** is either a 1 or a 0, depending on whether the site has been obtained or not. If a site has not been acquired, the entire term will be multiplied by 0, so the result in D50 will be 0. Since you have entered 0's in cells B50–B53, your initial values in cells D50–D53 will all be 0's. The long term in parentheses simply gives the suitability scores for site 1 for a given species, multiplied by the prioritization score for that species. When these values are summed, the result indicates the overall conservation value of a site.

Enter the formula **=SUM(D50:D53)** in cell D55.

The conservation value of the “habitat portfolio,” or the combined value of sites that actually are purchased, will be the sum of cells D50–D53. This is the value that we want to maximize in order to best use our limited conservation funds.

4. In cells F50–F53, enter formulae to compute how much money has been spent to purchase sites.

5. Open the Solver program.

6. Use Solver to change the choice variables to maximize the habitat portfolio, subject to the constraints that the choice variables are binary (0 or 1) and that you remain within budgetary constraints.

Thus, by entering a variety of 0 and 1 combinations in cells B50–B53, you can quickly see how different purchases will contribute to your conservation goals.

Enter the formula $=B50 * E42$ in cell F50. Copy the formula down to cell F53. The formulae in F50–F53 indicate how much money has been spent to purchase sites. If the choice variable is 0, the site has not been purchased, so no funds have been spent on that site.

Now you are ready to use Solver as described above to mathematically solve your optimization problem. Go to Tools | Solver and select Solver. The dialog box in Figure 8 will appear. (If Solver does not appear in the menu, go to Tools | Add-ins and select the Solver add-in.)

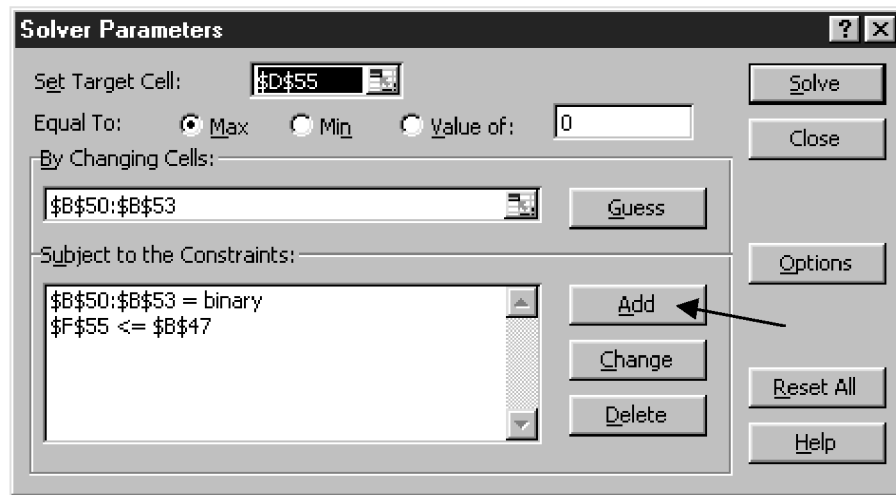


Figure 8

In the Solver dialog box, you are asked to Set Target Cell, which in our exercise is cell \$D\$55. We want to Maximize this value by allowing Solver to change the values in cells \$B\$50:\$B\$53 from either 0 to 1 or 1 to 0, depending on the initial conditions. Then select Add under the Subject to the Constraints box and enter your constraints:

- The first constraint is that cells **\$B\$50:\$B\$53 = binary** (“bin”), which means the data are either 0’s or 1’s. Make sure you use dollar signs when entering these constraints.
- The second constraint is that cell **\$F\$55 <= \$B\$47** (your total spending must be less than or equal to your budget).

When you are satisfied with your entries, select Solve and the program will find the optimal combinations of habitat that fall within the budgetary constraints. The solution will automatically appear on your spreadsheet.

In this case, given the prioritization and suitability scores, the optimal purchases are sites 2 and 3. You can keep Solver Solution, or Restore the original spreadsheet values. The program also can produce reports that supply more details about the model. If you click on the word Answer (Figure 9), the program will produce an Answer Report as new spreadsheet page in your workbook.

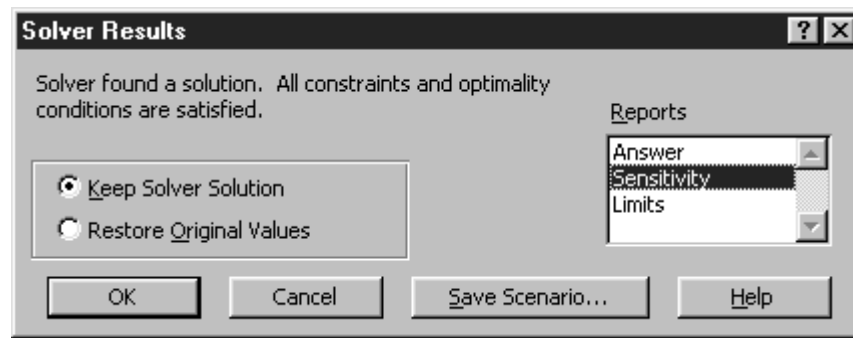


Figure 9

QUESTIONS

1. Fully interpret the results of your economic model and discuss which species are likely to benefit from the selection of sites made.
2. How “sensitive” is your model to the scores you assigned in cells C6–G8? Assume these cells can take on different values, and run Solver again. How do these changes affect your model results?
3. Site 4 appears to be suitable for several of the species but has a low probability of development. Restore cells C6–G8 to their original values. Increase the probability of development for site 4 in increments of 0.1, running Solver after each incremental increase. At what probability of development would site 4 be recommended for purchase?
4. Many criteria have been used to determine “suitability” of a habitat, including density, presence or absence of a species, and reproductive success. Densities, for example, are commonly used as an indicator of habitat quality: The more individuals there are in an area, the more suitable it is. Or is it that simple? Sometimes poor quality habitats have high densities, and high quality habitats may have low densities because of territorial behavior. Can you think of other measures that might be indicative of habitat quality?
5. In developing your suitability scores, we assumed that surveys occurred in a single year. We also did not consider the spatial arrangements of sites, and if certain sites are somewhat isolated from other protected sites. What are the benefits and shortcomings of developing suitability scores from a single sampling period? What information would you also like to add in terms of the spatial arrangement of sites in the landscape?
- *6. (Advanced) In developing your suitability model, you found that the different sites varied in both elevation and patch size. How would you learn which of these factors, or other unmeasured factors, most strongly shapes the distribution of a species?
- *7. (Advanced) In your model, the cost of a site is measured in dollars. However, many economists today believe that dollars do not always convey the true value of ecosystems (e.g., Costanza 1991, Hall et al. 2000). Discuss how land acquisition might be modified in the future to optimize conservation efforts.

LITERATURE CITED

Costanza, R. (ed.). 1991. *Ecological Economics: The Science and Management of Sustainability*. Columbia University Press, New York.

Hall, C., P. W. Jones, T. M. Donovan, and J. P. Gibbs. 2000. *Wildlife Society Bulletin* 28:16-25.

Hunter, M. L. 1996. *Fundamentals of Conservation Biology*. Blackwell Science, Cambridge, MA.

Hunter, M. L. and A. Hutchinson. 1994. The virtues and shortcomings of parochialism: Conserving species that are locally rare, but globally common. *Conservation Biology* 8: 1163–1165.

