Part Four

Experiences in Population Modeling and Population Viability Analysis 89

Exercise **12** **CREATING A STAGE-BASED DETERMINISTIC PVA MODEL—THE WESTERN PRAIRIE FRINGED ORCHID** 91

Carolyn Hull Sieg, Rudy M. King, and Fred Van Dyke

Background and Rationale *91*

Natural History and Conservation Status of the Western Prairie Fringed Orchid *92*

Stage-Based Deterministic Models *93*

Constructing the Model and Matrices *94*

Assignment 12.A: Determining Transition Probabilities between Stages 94

Assignment 12.B: Constructing Transition Matrices for the Western Prairie Fringed Orchid 95

Assignment 12.C: Calculating Population Data 96

Running the Model *97*

Assignment 12.D: Predicting Outcomes for Average Conditions 98

Assignment 12.E: Predicting Outcomes for Wet Conditions 98

Assignment 12.F: Predicting Outcomes for Dry Conditions 98

Questions and Assessment *98*

Synthesis *99*

Literature Cited *99*

Exercise **13** **THE CONCEPT AND USE OF ELASTICITY IN POPULATION VIABILITY ANALYSIS** 101

Carolyn Hull Sieg, Rudy M. King, and Fred Van Dyke

Background and Rationale *101*

Making Projections *101*

Assignment 13.A: Elasticity Analysis of Model Transitions 102

Assignment 13.B: Analyzing the Effect of Zero Seed Viability 103

Assignment 13.C: Analyzing the Effect of Zero Seed Viability with Increased Seed Production 103

Assignment 13.D: Analyzing the Effect of Zero Seed Viability Using the Wet Conditions Model 104

Questions and Assessment *104*

Synthesis *106*

Literature Cited *106*

Exercise **14** **USING STOCHASTIC MODELS TO INCORPORATE SPATIAL AND TEMPORAL VARIABILITY** 109

Carolyn Hull Sieg, Rudy M. King, and Fred Van Dyke

Background and Rationale *109*

Demographic and Environmental Stochasticity in the Western Prairie Fringed Orchid *110*

Assignment 14.A: Running a Stage-Based, Stochastic Population Viability Analysis Model 110

Adding Environmental Stochasticity *111*

Assignment 14.B: Running the Model with Three Climate Scenarios 111

Questions and Assessment *112*

Synthesis *113*

Literature Cited *113*

Exercise **15** **CONSERVATION AND MANAGEMENT APPLICATIONS IN POPULATION VIABILITY ANALYSIS** 115

Carolyn Hull Sieg, Rudy M. King, and Fred Van Dyke

Background and Rationale *115*

Simulating the Effects of Lowering the Water Table *115*

Assignment 15.A: Simulating the Effects of Drier Conditions and Lowering of the Water Table 116

Using Core Protected Areas in Orchid Conservation *117*

Assignment 15.B: Simulating Orchid Management Using Core Protected Areas 117

Global Climate Warming and Orchid Conservation *118*

Assignment 15.C: Assessing the Effects of Global Climate Warming 118

Water Table Drawdown, Global Climate Warming, and Grazing Management *119*

Assignment 15.D: Simulating the Effects of Multiple Factors at Once 120

Questions and Assessment *121*

Synthesis *122*

Literature Cited *122*

EXERCISE 15

CONSERVATION AND MANAGEMENT APPLICATIONS IN POPULATION VIABILITY ANALYSIS

In this exercise, you will learn how to:

1. incorporate and evaluate long-term environmental change, such as global climate change, into a stochastic population viability analysis model.
2. incorporate the effects of specific management strategies, such as establishing core protected areas, into a stochastic population viability analysis model.
3. evaluate combined, synergistic effects of long-term environmental change and specific management strategies on population viability and population fluctuation.

BACKGROUND AND RATIONALE

The western prairie fringed orchid is dependent on wetland habitat (U.S. Fish and Wildlife Service 1996). Prairie wetlands in which the orchid has historically thrived are usually ephemeral, filling with water in wet years and drying up during droughts. Wetland abundance and persistence is a function not only of variations in annual precipitation, but also of changes in groundwater levels beneath the prairie surface. The U.S. Fish and Wildlife Service makes this relationship explicit in its definition of wetlands by stating that "wetlands are lands transitional between terrestrial and aquatic systems where the water table (i.e., groundwater) is at or near the surface. . ." (Cowardin et al. 1979). Thus, in addition to having soil moisture relatively near the surface, the number, extent, and depth of prairie wetlands is strongly affected by the amount of groundwater present in deeper, more permanent reservoirs known as *aquifers*. During periods of high precipitation, some water falling or melting on the surface of a landscape percolates through the soil and reaches the groundwater, causing the water table to rise closer to the surface, and contributing to greater extent and persistence of wetlands. During dry periods, or when groundwater is removed from the aquifer directly by human activities, the level of the water table is lowered.

Although local human activities cannot directly influence annual precipitation levels on the prairie, human actions can and do cause changes in aquifer and water table levels. In this exercise, we use the same population model to examine the potential effects of lowering the water table on populations of the western prairie fringed orchid.

SIMULATING THE EFFECTS OF LOWERING THE WATER TABLE

Recall that the population model of the western prairie fringed orchid we have developed in exercises 12–14 is based on field data collected on *in situ* populations of orchids between 1990 and 1998. Western prairie fringed orchids, as noted earlier, are dependent on the occurrence of wetland habitats in prairies, and wetland abundance and distribution in this habitat is related to the depth of the water table. We have no data on orchid demographic rates after the lowering of the water table. However, recall from exercises 12 and 13 that populations of the orchid decline during dry periods or when the water table is well below the soil surface, and populations increase in response to wet conditions when the water table rises to levels at or near the soil surface. Thus, to simulate the effects of lowering the water table over a longer period than just 1 or 2 years, we increase the probabilities for the dry and average climate scenarios and decrease the probability for the wet climate scenario. In addition to having the likely effect of lowering the water table, an increasing frequency of average and dry conditions is also likely to reduce levels of soil moisture, a condition adverse to the orchid.

Assignment 15.A: Simulating the Effects of Drier Conditions and Lowering of the Water Table

1. Open the EXCEL workbook (from your workbook website at www.mhhe.com/conservation) as in exercises 12–14. Select "Enable Macros" when prompted.
2. Switch to the exercise 15 worksheet.
3. Select the Tools pull-down menu and choose "Macro."
4. Select "Macros," then "PVAStage," then "Run."
5. PVA Stage will ask for:
   a. *Length of time sequence*: Type "22."
   b. *Stage names*: Highlight column A, rows 4 through 8, or type "a4:a8."
   c. *Stage parameter for lambda calculations*: Select "Flowering plants."
   d. *Initial values*: Highlight column B, rows 4 through 8, or type "b4:b8."
   e. *Ceiling values*: Highlight column D, rows 4 through 8, or type "d4:d8."
   f. *Specification of first Lefkovitch matrix*: Highlight the average matrix, or type "b14:f18."
   g. *Next matrix*: Highlight the wet matrix, or type "b21:f25."
   h. *Next matrix*: Highlight the dry matrix, or type "b28:f32."
   i. *Next matrix*: Select "Cancel."
   j. *How the Lefkovich matrix should be selected*: Select "Random."
   k. *Selection probability for matrix 1*: Type "0.4"
   l. *Selection probability for matrix 2*: Type "0.2"
   m. *Selection probability for matrix 3*: Type "0.4"
   n. *Specify number of random sequences*: Type "1000" or select "Cancel" for the default of 1000.
   o. *Specify random number generator seed for matrix selection*: Select "97531."
   p. *Do you wish to specify element standard deviations?* Select "No."
   q. *Monitor minimum threshold*: Select "Yes."
   r. *Minimum threshold for flowering plants*: Type "50."
6. The program now provides a summary of the model specifications: Make sure it says:
   Sequence length is 22.
   Stage names from Exercise 15!A4:A8
   Initial stage parameter values from Exercise 15!B4:B8
   Stage ceiling values from Exercise 15!D4:D8
   Lefkovitch matrices from Exercise 15!B14:F18, B21:F25, B28:F32
   Random selection of matrices with selection probabilities = {0.4, 0.2, 0.4}, 1000 random sequence(s), with selection seed = 97531
   Minimum threshold of 50 will be monitored for flowering plants.
7. *Begin computations?* Select "Yes."
8. *Extended results*: Select "Flowering plants."
9. *Plot selected population parameters?* Select "Yes."
10. Select "Flowering plants."

Stop and Reflect

1. Make a list of some actions by private landowners or government management agencies that might result in lowering the water table, thereby, reducing the amount of wetland habitat.

2. What effect did lowering the water table have on the number of flowering orchids at the end of the simulation?

   a. How many flowering plants were present at the end of the simulation?

   b. Describe the 95% confidence interval for the population in this simulation.

   c. What was the final value of λ?

d. How does this compare to previous simulations under average, wet, or dry conditions?

e. What percentage of iterations showed populations of < 50 flowering orchids at year 22?

3. Assume that you are the manager of a district of public rangeland on which orchid populations are present. Based on these results, what overall management strategies could you implement or suggest regarding groundwater use that would contribute to the protection and persistence of existing orchid populations?

USING CORE PROTECTED AREAS IN ORCHID CONSERVATION

Multiple-use modules (MUMs) and "zonation management" are sometimes used to protect species or habitats of high conservation value in a landscape subject to multiple activities and uses (Noss and Harris 1986; Mech 1995; Van Dyke 2003). In such cases, a "core area" containing the most sensitive species, habitats, or other landscape elements is managed specifically to benefit these elements. Zones at increasing distances from the core experience increasing use and alteration. Such a strategy may be followed when complete protection from or elimination of disturbance is not feasible or desirable, or when a disproportionate number of individuals, habitat patches, or landscape elements of high conservation value exist in a relatively small and contiguous portion of an area subject to management regulation.

One of the most common human-induced environmental disturbances affecting orchids is grazing by livestock, especially cattle. Such grazing, which has long-standing historical precedent and local cultural significance and support, is an important economic component of many rural communities. For many long-term residents and their families, grazing is the economic basis of their survival in the area. Grazing, however, may have detrimental effects on orchid populations, depending on its timing, intensity, and frequency. Cattle can damage plants by grazing or trampling. Grazing can reduce the number of orchids that set fruit. Grazing may also function to create "regeneration niches" for the orchid or areas where reduced competition from other plants enhances orchid establishment (Bowles 1983).

On public lands such as those managed by the Bureau of Land Management (BLM) and the U.S. Forest Service (USFS), levels and types of grazing intensities are regulated, usually on individual grazing allotments and districts, by land managers who have authority, in conjunction with existing laws, elected political officials, and the public, to set grazing fees, determine the length of time and number of cattle using different areas, regulate some aspects of water use for irrigation and livestock, and prescribe other grazing management practices.

In a variation of assignment 15.A, we will employ these concepts as we again simulate the effects of lowering the local water table on orchid populations. However, in this case we will designate a "protected area" in which cattle grazing will be excluded at certain times of the year (when orchids are actively growing, flowering, and setting seed) from 30% of the available orchid habitat in "core pastures" that collectively support more than 80% of the orchid metapopulation.

Assignment 15.B: Simulating Orchid Management Using Core Protected Areas

Run the model as previously, but this time designate the three 30% ungrazed matrices in exercise 15 (I4:M8; I14:M18; I24:M28). Use the same climatic probabilities that you used in assignment 15.A: average = .4, wet = .2, and dry = .4.

Stop and Reflect

1. What effect did lowering the water table, but protecting 30% of the orchid habitat in "core" pastures, have on the number of flowering orchids at the end of the simulation?

a. How many flowering orchids were present at the end of the simulation?

b. Describe the 95% confidence interval for the population in year 22 in this simulation.

c. What was the final value of λ?

d. How does this value compare to the previous simulation in which there was no core protected area?

e. What percentage of iterations had < 50 flowering orchids at year 22?

f. How does this percentage compare to the percentage of the previous simulation in which orchids were not protected?

g. How might allowing cattle to graze in protected areas after the orchid has disseminated its seeds be beneficial versus completely excluding cattle from these areas?

GLOBAL CLIMATE WARMING AND ORCHID CONSERVATION

In North American prairie habitats today, evidence indicates that ongoing global climate trends are leading to higher average temperatures and lower average annual precipitation, conditions that contribute to lower levels of soil moisture, greater rates of evapo-transpiration, and overall higher levels of water stress in plants (Watson et al. 1998). Such changes have the potential to not only reduce soil moisture, but to lower water tables and reduce the size of wetland habitats (Poiani and Johnson 1991), effects that are likely to be detrimental to the wetland-adapted western prairie fringed orchid. In this assignment, we explore the possible effects of such trends by increasing still further the probability of dry environmental conditions and decreasing the probability of wet environmental conditions.

Assignment 15.C: Assessing the Effects of Global Climate Warming

Run the environmental stochasticity model as previously (see p. 111–112), but use the average, wet, and dry matrices in exercise 15 (b14:f18, b21:f25, b28:f32) and change the probability of the average scenario to 0.2, the probability of wet to 0.05, and the probability of dry to 0.75. (These changes are inserted to simulate both lowering the water table *and* global climate warming.) Then answer the following questions.

Stop and Reflect

1. How did lowering the water table, combined with global climate warming, affect the number of flowering orchids at the end of the simulation?

   a. What was the final population level of flowering orchids?

   b. Describe the 95% confidence interval of this population.

2. How do these values compare to simulations with water table drawdown only? With simulations including core ungrazed areas?

3. What was the final value of λ? How does this value compare to previous simulations in this exercise?

4. What percentage of iterations had < 50 flowering orchids at year 22?

5. How does this value compare to previous simulations in this exercise?

WATER TABLE DRAWDOWN, GLOBAL CLIMATE WARMING, AND GRAZING MANAGEMENT

Climatic changes and management practices often interact in unforeseen ways to affect the growth and persistence of populations. Models such as the one we have developed for the western prairie fringed orchid may be useful in examining different effects simultaneously and in identifying emergent, synergistic effects created by interactions that cannot be detected when each effect is considered separately. In the following assignment, we frame the model in such a way that the combined effects of water table drawdown, global climate change, and grazing effects, previously considered separately, will be allowed to operate simultaneously.

Assignment 15.D: Simulating the Effects of Multiple Factors at Once

Run the environmental stochasticity model using the core protected habitat (designating the three 30% ungrazed matrices in exercise 15) and the same climatic probabilities as used in the scenario of water table drawdown and global climate warming (average = 0.2, wet = 0.05, dry = 0.75).

Stop and Reflect

1. How did protecting 30% of the orchid habitat in "core" pastures when the orchid is actively growing, in combination with lowering the water table and global climate change, affect the number of flowering orchids at the end of the simulation?

2. What was the final population level of flowering plants?

3. Describe the 95% confidence interval of this population at year 22.

4. How do the population level of flowering plants and associated confidence intervals compare to previous simulations?

5. What was the final value of λ? How does this value compare with previous exercises?

6. What percentage of iterations had < 50 flowering orchids at year 22? How does this percentage compare with previous simulations?

7. How did water table drawdown, simulated by increasing the probabilities for dry and average climate scenarios, affect the predicted population size of western prairie fringed orchids, compared with average conditions?

8. How did climate change, combined with water table drawdown, affect predicted population levels of flowering orchids compared with average conditions? How did climate change affect the value of λ?

QUESTIONS AND ASSESSMENT

1. Do you think that it would be feasible to protect 30% of the orchid's critical habitat when the orchid is not actively growing (early June through mid-September) on public lands with historically high levels of livestock grazing? Why or why not? If this is possible, identify the potential obstacles to such a management strategy and how you would overcome them. If you think this is not possible, explain why the obstacles to implementing the 30% reserve strategy could not be overcome.

2. Is it possible that some level of livestock grazing could be beneficial to the persistence of the western prairie fringed orchid? Through what mechanisms and at what levels might such grazing increase the establishment, numbers, distribution, or persistence of orchid populations?

3. The effect of livestock grazing depends on its timing, intensity, and frequency. In this exercise, we altered the timing of grazing by protecting a portion of the orchid habitat when the orchid was actively growing.
   a. How could a manager also alter the *intensity* of grazing?

b. How could a manager alter the *frequency* of grazing?

c. How might changing the intensity or frequency of grazing be beneficial to orchids?

SYNTHESIS

These models demonstrate the effect of changing the probabilities associated with various climatic and management scenarios. We cannot forecast long-term climatic changes with certainty, and our data on demographic transitions of the western prairie fringed orchid represent data collected over only 9 years. It is possible that small changes in the amount or timing of precipitation could cause large changes in transition rates. Therefore, we cannot use these models to predict with certainty how many orchids will be present under varying conditions. However, we can learn from these simulations by comparing *relative* differences between the model outputs under different conditions.

These exercises demonstrate that protecting 30% of the orchid habitat in "core" pastures when the orchid is actively growing will result in increased growth rates of orchid populations, compared to no protection. However, land managers are often faced with the reality that, in spite of their good management, forces out of their control, such as climate warming, cause species to decline and even become extinct. Local land managers cannot control the weather, and often have little control over water management on adjacent lands. Although human beings cannot control the weather, they can plan and manage for its effects. Indeed, the ability to manage risk and uncertainty are key elements in all successful conservation efforts.

LITERATURE CITED

Bowles, M. L. 1983. The tallgrass prairie orchids *Platanthera leucophaea* (Nutt.) Lindl. and *Cypripedium candidum* Muhl. ex Willd.: Some aspects of their status, biology, and ecology, and implications toward management. *Natural Areas Journal* 3:14–37.

Cowardin, L. M., V. Carter, F. C. Golet, and E. T. LaRoe. 1979. *Classification of wetlands and deepwater habitats of the United States.* U.S. Department of the Interior U.S. Fish and Wildlife Service, FWS/OBS-79/31. U.S. Government Printing Office, Washington, D.C.

Mech, L. D. 1995. The challenge and opportunity of recovering wolf populations. *Conservation Biology* 9:270–287.

Noss, R. F., and L. D. Harris. 1986. Nodes, networks, and MUMs: Preserving diversity at all scales. *Environmental Management* 19:299–309.

Poiani, K. P., and W. C. Johnson. 1991. Global warming and prairie wetlands: Consequences for waterfowl habitat. *BioScience* 41(9):611–618.

U.S. Fish and Wildlife Service. 1996. *Platanthera praeclara* (western prairie fringed orchid) recovery plan. U.S. Fish and Wildlife Service, Ft. Snelling, MN.

Van Dyke, F. 2003. *Conservation biology: Foundations, concepts, applications.* New York: McGraw-Hill.

Watson, R. T., M. C. Zinyowera, and R. H. Moss, eds. 1998. *The regional impacts of climate change: An assessment of vulnerability.* Intergovernmental Panel on Climate Change. New York: Cambridge University Press.