The Ecology of *Opuntia fragilis* (Nuttall) Haworth

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Part I—Your New Career

Welcome to your new career as a plant population ecologist! As an ecologist, you are interested in how plants interact within a population, with other species, and with their surrounding environment. You have recently accepted a position at a university in central Minnesota and have been looking for an interesting plant species in the area to study. There is a county park being developed on 105 hectares of abandoned granite quarry land a few miles away from the university, and in a conversation you had recently with George, the Stearns County Parks Director, he mentioned that one of the plant species found in the parkland is *Opuntia fragilis*, the brittle prickly pear, which in his opinion should be on the Minnesota state list of endangered and threatened plant species.

Photo 1: Quarry Park, Stearns County, Minnesota.

You asked George to show you the population, and after walking through a scrubby red oak forest growing around piles of granite slag and water-filled quarries, you found an exposed granite outcrop about 20 meters long and 15 meters wide with several clusters of prickly pear growing along one edge of the outcrop. Immediately you fell in love with them. They are tiny, each joint about five centimeters long, bristling with spines, and sprawling over a mat of brownish moss growing in a crack in the granite. If you look at the illustration above, each rounded structure is a joint, often called a cladode or a pad; the yellower end structures are the new growth. By the way, botanists call these pads cladodes; they are really stem segments. Cacti leaves are modified into spines. If you look at the picture of prickly pears shown here you can see how the entire plant sprawls over moss. You quickly realized that this species might be an ideal organism to study—it is relatively easy to find and identify, quite rare, the population is completely isolated, with nice discrete boundaries, George would love to have you investigate the ecology of *Opuntia fragilis* at the park, and you can work on your suntan while you study them.

Photo 2: Prickly pears growing in moss on a rock outcrop.

Now you are sitting in your office, your head bursting with ideas and questions. Where should you begin? You've already spent some time in the library and have some basic information. Particularly valuable was a book by Lyman Benson (1982), *The Cacti of the United States and Canada*. In this book, Benson refers to brittle prickly pear several times. The book has a range map (see Figure 1, next page) showing that *Opuntia fragilis* is widely scattered across 25 states and five Canadian provinces. However, in most of those regions the populations are widely scattered and the plant is actually quite uncommon.

You learn that *Opuntia fragilis* was one of the first four species of cacti collected from the U.S. interior, and was first collected by Thomas Nuttall on the shores of the Missouri River. *Opuntia fragilis* occurs up to latitude 58 degrees in northern Alberta and British Columbia, where winter temps can be -40 degrees C. Benson proposed that its prostrate

Figure 1: Approximate distribution of *O. fragilis* in North America. Redrawn after Benson 1982 and other information.

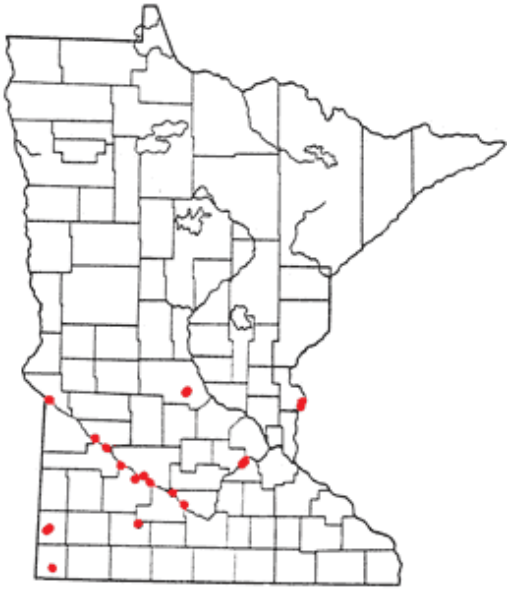

Figure 2: Approximate distribution of *O. fragilis* in Minnesota. Based on Ownbey and Morley, 1991.

growth form and thickened pads are both adaptations to a cold climate. He reasoned that these traits were adaptive to cold, because the low growth form means it is quickly covered by protective snow, and thick pads provide a reduced surface-to-volume ratio. Both of these traits would reduce freeze damage.

Benson also mentioned that the dry fruits are capable of epizoochorous transportation (i.e., they get stuck in the fur of animals). In his opinion the wide northern range of *Opuntia fragilis* was caused by the easy fragmentation of the pads. Benson wrote, "The plains buffalo occurred in enormous herds, and their great hairy bodies would have been ideal for transporting the small cactus joints. The places where buffalo lay down probably included many plants of *Opuntia fragilis*." According to Jack E. Schmautz, U.S. Forest Service (personal communication, 1976), the cactus is common at the edges of "slick spots" formed on solodized solonetz soils in eastern Montana and western North Dakota. These areas "were probably buffalo wallows." According to Larry W. Mitich (personal communication), the species flowers only sparingly in North Dakota. Ownbey and Morley (1991), in their book about the plants of Minnesota, stated that *Opuntia fragilis* is scattered across the state, with most populations growing along the Minnesota River, but with several disjunctions, including the population in Stearns County. In Minnesota, Ownbey and Morley (1991) show that it is found in your county, but not in any other county within 80 miles (top central dot, Figure 2).

How should you begin your research? What questions do you want answered? What should you do to find the answers? Decide what your plans are and design your first summer of field work. Show your design to your instructor, and then proceed to Part II of the case.

Questions

1. What kinds of questions do population ecologists ask?
2. Why don't we already know all we need to know about the ecology of *Opuntia fragilis*?
3. Why is it unusual to find a cactus species in the northern United States and Canada?
4. When populations occur in different regions, but not in the regions in between, we call that a disjunction. The scattered red dots in the upper midwest in Figure 1 are disjunctions. Why are disjunctions interesting to plant ecologists?
5. What does it mean when we say *Opuntia fragilis* should be a threatened plant species in Minnesota?

Part II—Your First Year Plans

One of the most fundamental questions population ecologists want to answer is: *How big is the population?* You decide to answer this question for the population of *Opuntia fragilis* in the new quarry park. You want to know how many different plants there are as well as how many individual pads there are. You plan to survey the entire rock outcrop in the park, building a map of the locations of prickly pear, the rock outcrop segments, trees, and grassy vegetation. You will record the location of each individual and count the number of pads that the individual has produced.

Photo 3: *O. fragilis* growing on a rock outcrop (look up and to the left from the leather case).

A second question population ecologists want to have answered is: *How is the population structured?* This question involves answering several different questions, including: *How many individuals are there of each sex? How big are they? How old are they?* For your prickly pear, the questions are a bit simpler, because you have no way to determine how old an individual is and because prickly pears produce perfect flowers, with both male and female parts, which means that you will not have to keep track of separate sexes. Thus, you will be able to explore the population structure question by figuring out how big the plants are, which you can tell by counting the number of pads an individual has.

A third fundamental question in population ecology is: *How much does the population change from year to year?* You know that the number of individuals next year will be the number of individuals present this year, plus the number of new individuals produced, minus the number of individuals that die. Because the population is isolated, you don't have to worry about emigration and immigration. This question will take at least two years' worth of field work to answer. The first year you will need to gather initial population size data, and then develop a second year's census to provide a basis for comparison. You know that you will need to mark and carefully map the location of individual plants so that you can return the following year to determine whether each individual is a new plant, has died, or how much it has grown in size.

You realize that each *Opuntia fragilis* pad could be thought of as a separate individual, because you know that the pads can break off the parent plant and form a new plant on their own. This method of reproduction is asexual, producing genetically identical individuals. Therefore, you hope to be able to calculate population growth both in terms of the number of individual plants and the number of individual pads.

In addition, you know that *Opuntia fragilis* also can reproduce sexually by producing fruit. You decide that you want to watch for flowers, record how many flowers each plant produces, and revisit the site later in the year to determine which flowers have produced fruit. You will dissect some fruits to determine how many seeds each flower produces.

Finally, of course you plan to spend more time reading about this plant in the library, and you want to explore the region around the new park to see if there are other populations of *Opuntia fragilis* on nearby rock outcrops.

Questions

1. Did your research plan cover each of the three fundamental questions of population ecology?
2. One of the challenges of being a scientist is deciding which questions are the most important and keeping your project small enough that you can actually finish it. What else could you be doing that is not included in the research plan described above?
3. What kinds of tools and supplies will be needed? Who is going to pay for them?
4. Does it matter that buffalo used to be found in Stearns County but have been eliminated long ago by hunting? What other animals might be important to the ecology of prickly pear? Should your research plan consider these questions?

Part III—Your First Year Results

You explored the region around the new park to see if there are other populations of *Opuntia fragilis* on nearby rock outcrops. You used topographic maps to find areas where rock outcrops could be found nearby, and you examined each rock outcrop. You found one previously undocumented population. Also helpful for this aspect of your research project was the university's retired botanist, Nick. Nick told you that there were several small populations growing on rock outcrops along a road near the park, and one large population on a granite hill about 15 miles away. One of the populations turned out to have been destroyed by a recent road expansion, but the others were still there. You added these populations to your research, so that now you have four sites.

Photo 4: Woods Site—has six individual plants scattered on the rock outcrops (you can't see them, but they are there).

You surveyed the entire rock outcrop in each site and created a map of the locations of prickly pear, the rock outcrop segments, trees, and grassy vegetation (see Figure 3). You planned to record the location of each individual and count the number of pads that the individual has produced. However, you discovered that in several sites there were large clusters of prickly pear pads, one with more than 100 pads. In the clusters you were not able to distinguish individual plants. Therefore, you modified your original plans and marked the location of clusters without counting the pads within the clusters (remember a cluster may be one large or several smaller individual plants).

How big are the populations? You wanted to know both how many different plants there are and how many individual pads there are. Cold Spring Hill had the largest population of *Opuntia fragilis*; you found at least 230 plants. Your original site, Quarry Park, had the second largest population, with about 100 plants. A site on a small outcrop nestled into a woods, which you named the Woods Site, had only six individual plants, and a site on a small flat rock outcrop which you named the Table Site had only one large cluster covering about two square meters.

You also wanted to know how the populations were structured in terms of the size of each individual. The table in Figure 4 shows for each possible number of pads how many plants you found with that number of pads, added up over the four sites. Note that several plants had more than 10 pads, and are included in the "10" column.

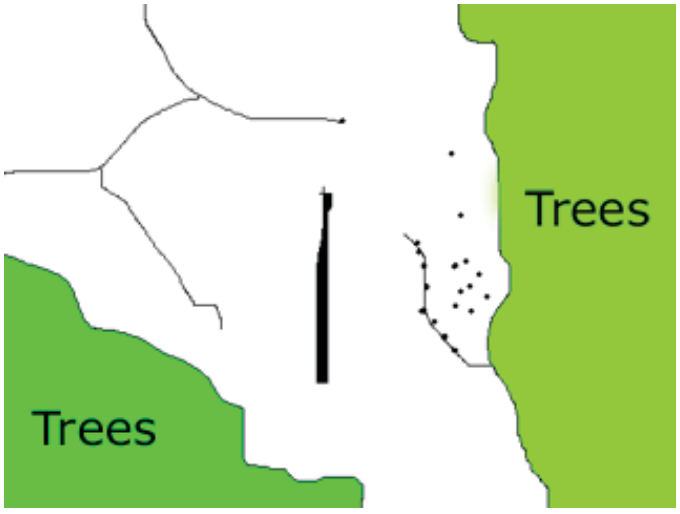

Figure 3: Quarry Park. Green areas are grassy. The black lines are cracks in the granite, and the long black object is a fallen tree. *O. fragilis* plants are marked with black circles.

In June you watched for flowers. You planned to record how many flowers each plant produced and then revisit the site later in the year to determine which flowers had produced fruit. However, you discovered that only four flowers were produced in one entire population, one flower at another site, and two sites never produced any flowers! Furthermore, no fruits were formed. Therefore, your plans to observe the flowers and dissect the fruits had to be set aside.

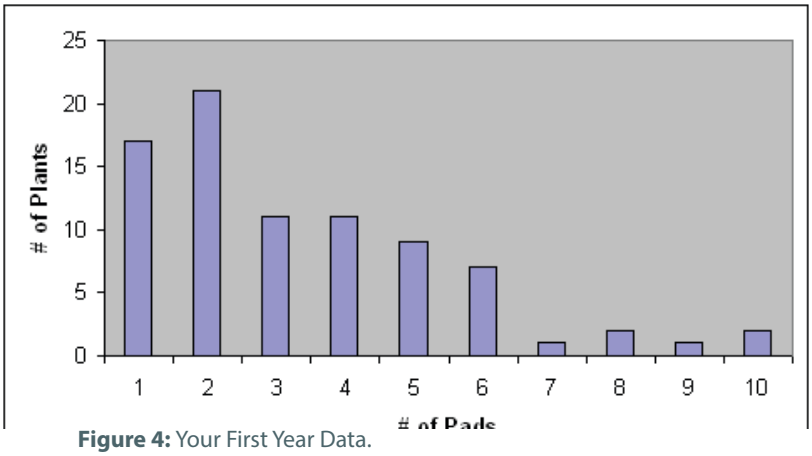

Figure 4: Your First Year Data.

Questions

1. What does the map of the site tell you (Figure 3)?
2. What does the bar graph of plant sizes tell you (Figure 4)?
3. What changes did you make in your research plans? Does the fact that you had to change your plans mean that you are a poor scientist?
4. In your library research, you discovered a research article published by Frego and Stanisforth (1986), two Canadian scientists who studied *Opuntia fragilis* on rock outcrops in Manitoba and western Ontario. They reported that in their study sites, the brittle prickly pear only reproduces by fragmentation. Thus, no sexual reproduction is occurring in their populations, and the population expands by having individual pads break off and become established elsewhere on the site. This intrigues you, because you also found no successful sexual reproduction. What are the implications for the population if it is only reproducing asexually?


Photo 5: *O. fragilis* in bloom.

5. In another article, Frego and Staniforth (1986) point out that isolated populations of *Opuntia fragilis* in Ontario are always located along rivers. Citing the earlier work of Szczawinski and Turner (1980), the authors speculate that they were possibly spread by Native Americans, perhaps because they used the spines as fish hooks. Should you change your research plans to try to answer this question? If so, how would you change it? If not, why not?
6. What does it mean that no fruits were produced this year? Does it mean the population never reproduces sexually? What should you plan to do?
7. What should you do in the second year of research? Decide what your next research plan is.

Part IV—Your Second Year

By carefully building maps of the populations and by repeating the survey, you had hoped to be able to calculate population growth both in terms of the number of individual plants and the number of individual pads. When you returned to each site you discovered that your map of Quarry Park, your first site, was different enough from what you saw the second year that you were unable to determine accurately which pad was which. However, your other maps were designed more accurately, and you were able to relocate most individuals you measured last year. You counted the pads on each plant again, looked for new individuals, and watched for flowers again.

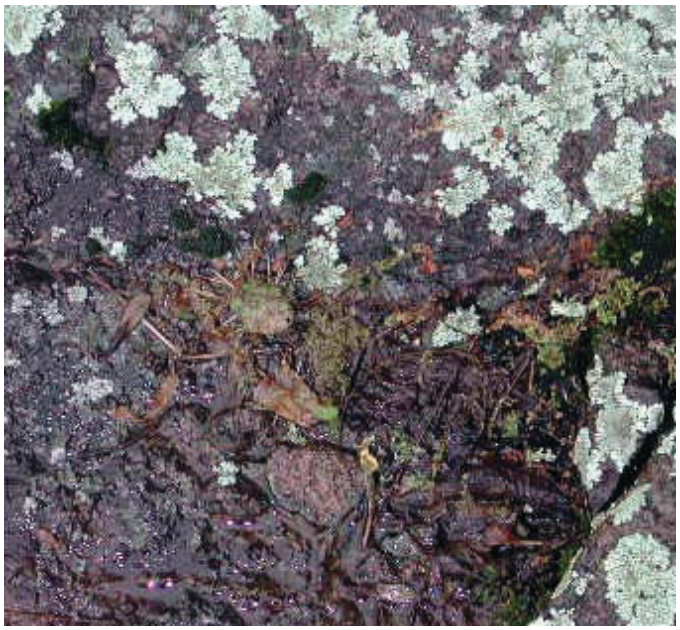

Photo 6: A dying single pad.

You found that between your first survey and the second, 7 of 136 plants died. You tracked a number of pads on the surviving plants. Of these, 37 pads disappeared, 82 produced new pads, and 251 stayed alive but did not produce new pads. You also found that the average plant size increased from 2.70 pads to 3.19 pads. You only found two flowers, and neither flower produced any fruit. You also discovered five plants, one 12-pads big, on the edge of the Quarry Park outcrop, which you had not mapped last year.

Questions

1. Are the populations growing?
2. If you started with 370 pads and 37 pads disappeared, and if we assume that 75% of the disappeared pads eventually died, is the population growing?
3. Given the numbers in question 2, if we assume that the rate of disappearance is not influenced by the age of the pad, by the time 90% of the pads have died, how old are the survivors?
4. Why don't the flowers produce fruits (and thus seeds)?
5. What should you do about the five new plants you found?
6. What should you do next?

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