Title

Mt. Graham Red Squirrel Case Study from the Structured Decision Making Workshop
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Decision Problem

The challenge for our team was to develop a transparent decision-making process by which the USFWS and MGRS Recovery Team can derive the criteria necessary to reclassify (downlist) and remove (delist or recover) the red squirrel from the list of threatened and endangered species. To address this problem, we used a structured decision-making process as a tool to work through and address the issues associated with developing recovery criteria. Our goal was to learn the process and eventually facilitate a structured analysis with the decision makers. The following is what we learned.

Background

Legal, regulatory, and political context

In 1987 the Service listed the MGRS as endangered with critical habitat, which is contained within an area designated as the Mt. Graham red squirrel Refugium. The species' recovery priority is 9c, pursuant to the Endangered and Threatened Species Listing and Recovery Priority Guidelines (48 FR 43098 and 48 FR 52985). A 9c classification indicates the taxon is a subspecies with a moderate degree of threat, a high recovery potential, and it is in conflict with development projects or other economic activity. This red squirrel historically inhabited only mature to old-growth associations in mixed conifer and spruce-fir above about 2,425 meters (m) (8,000 feet (ft)) in the Pinaleño Mountains of Graham County, Arizona. These mountains occur entirely on the Safford Ranger District of the Coronado National Forest, administered by the U.S. Forest Service (USFS).

The original MGRS recovery plan was finalized in 1993. Since that time, knowledge of the biology and threats to the species has changed substantially. The ESA requires the Service to revisit recovery plans every 5 years, yet no revision to the original MGRS recovery plan has occurred in 15 years. For over 18 months, revisions to the Mount Graham red squirrel (MGRS or red squirrel) recovery plan have been languishing due to an inability to derive and agree upon

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recovery criteria for the squirrel. While the ultimate decision maker is the Region 2 Director of the US Fish and Wildlife Service (Service) and the Director of the Arizona Game and Fish Department (AGFD), the Service has been working with the Recovery Team to try to update and revise the recovery plan.

Ecological context

The apparent limiting factors for MGRS are habitat, predation and interspecific competition. The MGRS requires full, forested canopy cover for arboreal travel and some protection from aerial predation in specific forested areas in the Pinaleño Mountains. Conifer cone crops must be adequate; thus several conifer species must be available in case one tree species' cone crop fails. Microclimates of cool, moist conditions near and at the base of large, mature, old growth conifers (the preference appears to be spruce-fir and Douglas fir trees), along with large-diameter snags and dead and down logs, allow the red squirrel to create middens (deep piles of cone scales) and bury closed conifer cones to excavate and eat throughout the winter into spring. Mature trees in old growth conditions can range between 100 to 300 years old and are not easily replaced when lost. These trees have specific requirements on the mountain. Young red squirrels need areas suitable for dispersal.

New threats are confounding the recovery of MGRS. Lack of fire has led to an unhealthy forest with dense trees. The increased tree density has led to severe fires and insect outbreaks, decreasing the habitat of the squirrel. The current habitat still faces unacceptable threats of more severe fire and more insect outbreaks. While forest restoration efforts appear necessary to protect the remaining habitat of the squirrel, those same efforts could remove habitat components necessary for survival.

Decision Structure

Our objective was to develop defensible recovery criteria specific to the MGRS. To do this, we followed the roadmap laid out by the structured decision-making process, as illustrated in Figure 1 (page 7).

State Variables

The ESA dictates general recovery criteria must be objective and measurable and refer to: 1) loss of habitat, 2) overutilization, 3) disease or predation, 4) inadequacy of existing regulatory mechanisms, and 5) other natural or manmade factors. These, therefore, were our constraints, under which our objective was to identify the specific factors and values that relate directly to these general criteria.

Conceptual Model (Influence Diagram)

We identified specific factors that were causing MGRS decline and influencing population size (i.e., factors influencing birth and death rates) (Table 1, page 6). We developed an influence diagram to illustrate the relationships between these factors (e.g., precipitation affects fire and food resources). Our influence diagram is illustrated in Figure 2 (page 7).

We quickly realized that the MGRS is not adversely impacted by all of these possible listing factors. In our first prototype, we wanted to include factors that most directly affected the

MGRS, and therefore needed to eliminate those that did not have a significant impact on the squirrel. For example, overutilization currently is not a threat to the MGRS, as they are not a hunted species in Arizona, and the regulations protecting them are adequate; we eliminated other parameters because currently they do not pose a significant threat to the MGRS (e.g. elk, recreation, development, etc.). Among all the listing factors, we identified available habitat, predation, and competition with Abert's squirrels as the most critical issues. Additionally, we simplified some of the links between parameters to aid in our rapid prototyping process. For example, we know Abert's squirrels primarily impact red squirrel numbers by impacting their food resources, even though they also impact their habitat. For simplicity, we modeled the impact of Abert's only on the food resources and not on the red squirrel habitat. Also, we know that avian predation has a significant impact on the red squirrel population, but we realized our demographic data (age classes, mortality rates, survival rates) already incorporated predation impact (red squirrels can live 6-8 years usually, but research has indicated the MGRS does not live much beyond 2 years). Therefore, for our quantitative analysis, we did not incorporate additional impacts from predation. Our simplified conceptual model is illustrated in Figure 3 (page 8) and includes only two listing factors, habitat loss and other factors; predation is incorporated, but assumed to be part of the demography.

Alternative actions

We did not explore alternative actions because our alternatives would have been to choose a process other than structured decision making to develop defensible recovery criteria for the Mt. Graham red squirrel.

Predictive model

In order to predict the consequences of our influence diagram in relation to our objective, we constructed a stochastic population model in Excel to simulate MGRS dynamics as function of listing factor conditions. With this model, we can test different actions, and show that by reducing the threat of Abert's squirrels, reducing the threat of fire, increasing current habitat, or some combination of the three factors, we might eventually reclassify and recover MGRS.

Objectives

Using the quantitative model, we could test different levels of influence and derive persistence levels (outcomes) to compare with our objective (95% chance of persistence over 100 years), finally deciding upon a decision rule that would satisfy our objective. See Decision Analysis below for a description of our decision rule.

Decision Analysis

We used the predictive model to solve for the combination of fire probability, starting habitat and Abert's squirrel abundance that would allow the MGRS population to meet our reclassify or recover objective (to have a 95% expectation of persistence over 100 years). The solution is graphically illustrated in the Pareto diagram below (Figure 4, page 8), which shows a range of values for listing factors most important to MGRS status. For example, if we have a certain amount of suitable habitat to start and lose a certain amount of habitat to fire, as represented by the green diamond, we use the model to determine what level of competition from Abert's squirrels is allowable to reclassify the red squirrel from endangered to threatened (e.g., if the competition with Abert's squirrels is low).

Uncertainty

For us, uncertainty was mainly about the effects of one factor on another. For example, we weren't sure how each Abert's squirrel affected each MGRS, nor what the magnitude of the effect was. To address this, we made educated guesses to the extent that we could. Dealing with uncertainty in this way also showed us areas where we can focus future research and literature searches to address some of this uncertainty.

Discussion

Value of decision structuring

This decision structure provides advantages over how the problem has been approached in the past. The advantages include a transparent process through which all members of the Recovery Team can evaluate the factors influencing the births and deaths of the MGRS, and the ability to manipulate these factors (through sensitivity analysis) to determine which have the most influence over squirrel numbers. Ultimately, this should allow us to develop defensible recovery criteria upon which the Recovery Team can agree.

Further development required

The next step is to work through this process again with a small subset of red squirrel experts from the Recovery Team. We will develop an influence diagram with them and begin building a model in which they can decide which parameters are the most important and how they might be manipulated. Elements of this new prototype model that need to be developed further include refining our understanding of the impacts of Abert's squirrels on the MRGS, incorporating elements from existing fire models and cone crop production models, and life history parameters of the red squirrel. When we have worked through this prototype, we will bring in the entire Recovery Team and continue to work with them to refine a model that includes all of the factors identified by the Recovery Team and the uncertainty associated with them. The strength of this approach is that we incorporate the listing factors up front in the model, making the model a management tool more than simply a biological model, and allowing us to determine listing criteria, not just simulate the MRGS population.

Prototyping process

We felt the rapid prototyping process worked well for our group. It allowed us test a model and see where the model would take us; it helped us to visualize what kind of end solution we might be able to develop. Those in the group that had more modeling experience feared we might need a spatially explicit population dynamics model and were surprised that we were able to use a spreadsheet quantitative model. Those in the group with no modeling experience were impressed at the entire methodology of structured decision making. Our consultant was able to keep us from getting bogged down in the details by encouraging us to use the best data on hand or educated guesses, just to get started, and it worked well to eliminate some variables that were complex or less significant. Although team members without modeling experience could not keep up with the initial modeling structure, going back and explaining it to those members helped the team plan how to explain it to other stakeholders upon returning from the workshop.

Recommendations

We believe that reclassification and recovery criteria for MGRS can be developed by use of a model similar to the one developed during the workshop. The quantitative model that links listing factor values to persistence will allow the Recovery Team to solve for the Pareto surface describing levels of listing factors (variables) that can be identified for reclassification and recovery criteria.

We will now redesign the model, using experts on MGRS. We will research data needs from literature and from expert opinion. Then we will take this draft model to the Recovery Team and show them how this concept can be used to develop reclassification and recovery criteria.

Literature Cited

Hammond JS, Keeney RL, Raiffa H. 1999. Smart Choices: A Practical Guide to Making Better Life Decisions. Broadway Books, New York.

Tables

Table 1. Factors influencing birth and death rates of Mt. Graham red squirrels within the context of the five listing factors (constraints).

Habitat Loss	**Overutilization**	**Disease/Predation**	**Regulations**	**Other factors**
Fire		Avian predators		Abert's Squirrel
Elk				
Recreation				
Abert's squirrel				
Insects				

Figures

Figure 1. Structured decision-making process for developing recovery criteria for the Mt. Graham red squirrel.

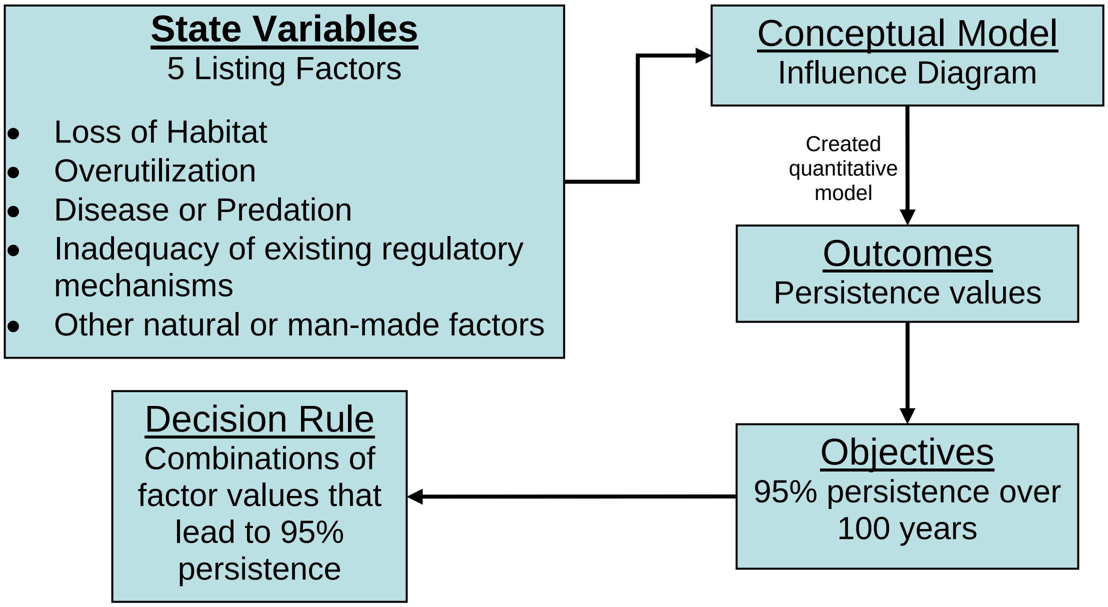

Figure 2. Influence Diagram for the Mt. Graham red squirrel.

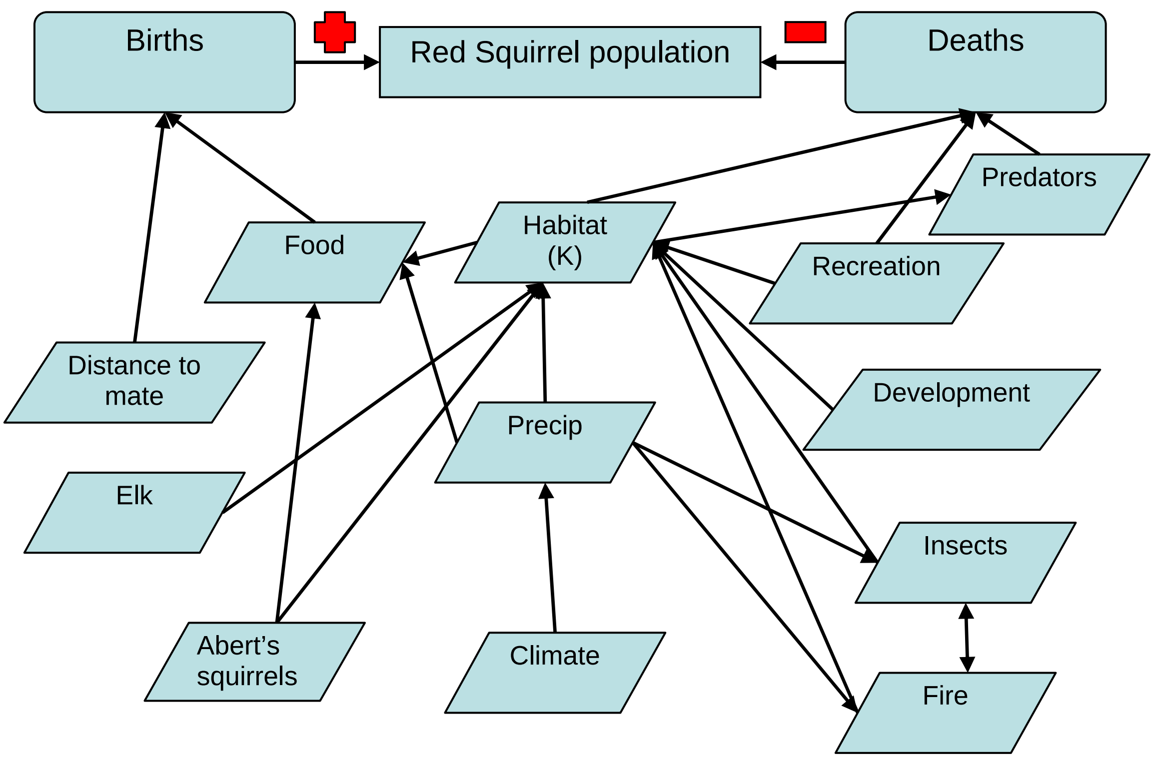

Figure 3. Simplified conceptual model for the first prototype predictive model for the Mt. Graham red squirrel.

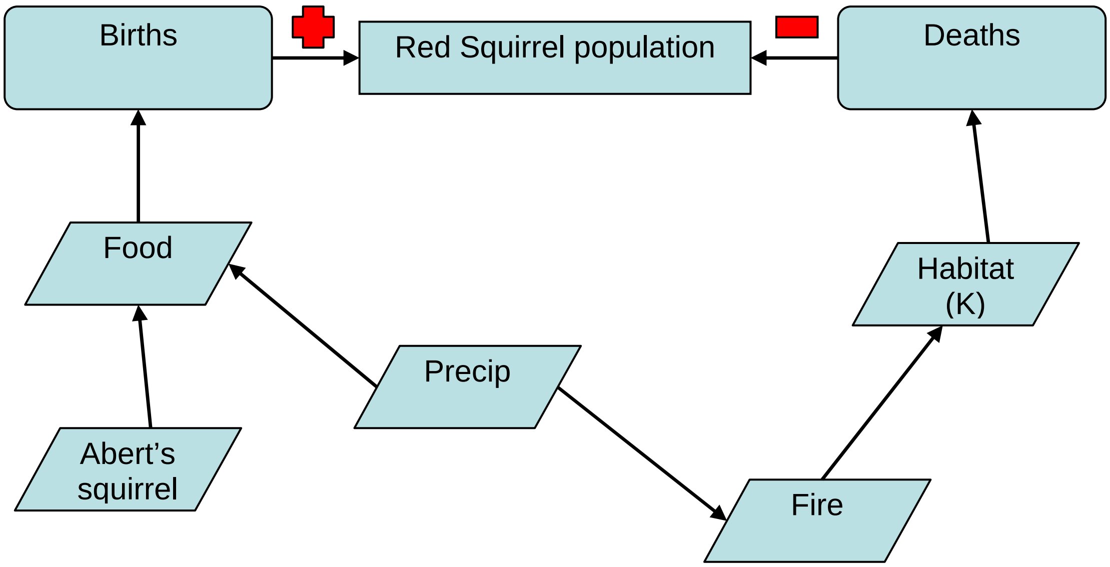

Figure 4. Pareto diagram illustrating the range of alternative results based on three of the factors important to the listing status of the MGRS (amount of starting habitat, area of habitat burned in 100 years, and competition with Abert's squirrels).