An Ecological Problem-Solving Process for Managing Special-Interest Species[1]

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Abstract.—We present a structured problem-solving process that can help resolve wildlife management issues. Management goals for wildlife species are expressed in terms of populations to be attained and maintained. Habitat quantity and quality necessary to achieve those population goals can then be determined. Proposed land-use changes are evaluated in terms of how they will contribute toward recovery or extinction of the species of interest.

Land-use problems associated with the need to protect wildlife habitat and the desire to develop resources can sometimes be resolved using an ecological problem-solving process. The process requires development of a management goal for individual wildlife species, determination of the quantity of habitat required to achieve that management goal, and an appraisal of how development scenarios will affect the management goal.

We describe how the process might work using available data about the endangered Mount Graham red squirrel *(Tamiasciurus hudsonicus grahamensis)*. The exercise is relevant because the squirrel exists entirely as a disjunct population in the high elevation coniferous forest community of the Pinaleno Mountains of southeastern Arizona, and a new astrophysics observatory has been proposed within important squirrel habitat. Our process was not applied in the development of the Environmental Impact Statement (EIS) prepared for the red squirrel and its habitat nor in negotiations for the future management of the squirrel. An extensive and current information base (Spicer et al. 1985; U.S. Forest Service 1987, 1988) recently has been developed for the Mount Graham red squirrel in order to develop the EIS for the proposed astrophysics observatory. We applied these data to a cumulative impacts assessment process being developed by the U.S. Fish and Wildlife Service. We assume that species-habitat management goals can be developed and that these goal statements can drive habitat management plans and activities. We have not analyzed the merits of any development scenarios proposed for the astrophysics observatory.

The Pinaleno Mountains are an isolated range that supports one of the southernmost spruce-fir forests in North America (Spicer et al. 1985). The Mount Graham red squirrel is endemic to the small patches of coniferous forests that occur at the highest elevations of the mountains. The squirrel has been affected by a variety of human activities and natural events that have altered its habitat. Disturbances included completion of a road to the mountain top in 1933, introduction of the tassel-eared squirrel *(Sciurus aberti)* in 1941 to 1943, extensive logging activities in subalpine coniferous forests from 1946 to 1973, a major fire in 1956, and extensive windthrows in the 1960's (Spicer et al. 1985). The squirrel was first collected from the Pinaleno Mountains in 1894 and was considered "common" in the spruce-fir zone above 2,590 m in 1914. Since the early 1950's it has been considered "uncommon" throughout the coniferous tree zone of this mountain range (Spicer et al. 1985).

THE PROCESS

The problem-solving process used in our analysis contains three principal steps (fig. 1). Problem description, the first step, defines the ecological problem and identifies the species, study area, and time frame of concern.

Problem analysis, the second step, develops biological information necessary to achieve a solution. An initial effort is to describe a management goal for the species of concern in terms of a specific population level to be achieved and maintained. This numerical target is not a vague statement to "maintain" or "enhance" because such terms cannot be used to measure the results of management actions. The management goal should be collaboratively developed so that all interested parties reach a consensus on the desirability for perpetuating the species and on a population level to be achieved by management. It is understood that mutually agreed upon goals represent compromise and that compromises are rarely satisfactory to all concerned parties.

It is then necessary to determine the quality and quantity of habitat

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required to achieve the management goal. This requires building a model describing habitat requirements for the species. An understanding of how human activities and natural events impact habitat quality and quantity is also desirable because the management of these restricting actions may help achieve the management goal for the species. The identification of causes contributing to habitat deficiencies can be made by interviewing persons familiar with the species and the particular habitat conditions within the study area.

The third step in the process, solving the problem (fig. 1), is accomplished after: (1) the amount and quality of habitat necessary to fulfill the management goal has been determined, (2) the quantity of suitable habitat presently available has been documented, and (3) the quantity of suitable habitat that would be available under different land-use options has been projected.

I. Describe the Problem

II. Analyze the Problem

1. Determine the Management Goal for the Species.
2. Describe Important Habitat Conditions for the Species.
3. Determine how Human Activities Affect Habitat Conditions Important to the Species.

III. Solve the Problem

1. Determine Acceptable Strategies for Managing Habitats Required by the Species.

Figure 1.—Steps of the problem-solving process.

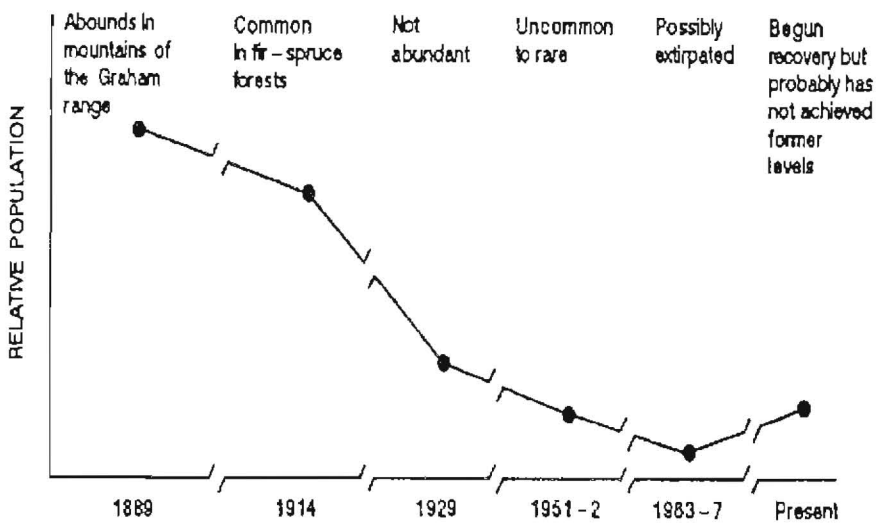

Figure 2.—Possible trends in abundance of the Mount Graham red squirrel. (Population descriptions are those of Spicer et al. 1985.)

Describe the Problem

The Mount Graham red squirrel has probably declined during this century (fig. 2) in part because of the piecemeal degradation of isolated forest habitat. The variety of human activities and natural events causing this decline might soon be augmented by the development of the astrophysics observatory on the Pinaleno Mountains. Can this and related developments occur in a manner that does not further jeopardize the existence of the endangered red squirrel during the foreseeable future?

Analyze the Problem

Determine the Management Goal for the Species

The management goal is described in terms of a population to be attained and maintained. Ideally, population goals should be based on quantitative historical levels of abundance. Population goals are more difficult to establish if historical information about population levels are fragmentary and descriptive, as for the Mount Graham red squirrel. In such cases, criteria for establishing desired population levels should consider: (1) estimates of present populations and trends, (2) threshold values necessary to ensure the survival of the species, and (3) estimates of the potential population level that could be attained if management of an area was accomplished solely to benefit the species.

Estimates of population trends for the Mount Graham red squirrel are largely qualitative (fig. 2). The results of field work suggest that the autumn 1987 population of red squir-

rels on the Pinaleno Mountains might be 246 (206-286), (U.S. Forest Service 1988:37). Computer simulations of population dynamics of the red squirrel (U.S. Forest Service 1988:74) are only minimally helpful because data such as natality and mortality for the Mount Graham red squirrel are unknown. The computer simulations suggest probability levels for extinction under different combinations of mortality and reproduction. The predicted carrying capacity for the squirrel under current habitat conditions has been estimated at 502 squirrels. The potential future carrying capacity, based on the quantity and present age structure of mixed conifer and spruce-fir stands, is 725 squirrels (U.S. Forest Service 1988:72-73). Thus, the current population of red squirrels might be somewhat higher than that in the early 1960's when the species was reported as possibly extirpated (fig. 2), but less than one-half the present carrying capacity for the species. The collaboratively developed management goal might state, for example, that the management goal for the species is to develop and perpetuate a red squirrel population equal to the present carrying capacity of the habitat for the squirrel which is estimated at 502 squirrels (U.S. Forest Service 1988:73).

Describe Important Habitat Conditions for the Species

A species-habitat model for the red squirrel can be based on the squirrel's dependency on seed cones and trees that produce those cones. Conifer seeds are the primary food of the red squirrel, which cuts cones in summer and caches then in middens in dense needle litter at stumps, downed timber, and on the base of snags or live trees in forests with dense overstory canopies (Spicer et al. 1985).

We constructed a species-habitat model for Mount Graham red squirrels using data given in the U.S. Forest Service (1987) report. The structural stage, tree species, and canopy density that compose red squirrel habitats are classified as excellent, good, fair, poor, very poor, and no value (fig. 3). These data were developed by U.S. Department of Agriculture Forest Service personnel and others familiar with the habitat requirements of the squirrel and were based on vegetation type and structural stage, the number of snags and downed logs per hectare, aspect, and slope (U.S. Forest Service 1987:44). Midden complexes are a focal point of territories and the number of active middens is supposedly associated with the number of red squirrels in a stand (Spicer et al. 1985). The data for middens per hectare have been adjusted so that a score of 1.0 is listed for excellent habitats, 0.0 for no value habitats, and intermediate values are listed for habitats of intermediate quality (fig. 3).

The species-habitat model describes conditions in habitats of different quality. A simple word model was then developed to describe a unit of good or excellent habitat for a red squirrel (fig. 4). The model developed from information in figure 3 and U.S. Department of Agriculture (1987:33-37) defines suitable habitat for a red squirrel as a 1-ha forested block that: (1) is contiguous to other similar forested blocks, (2) provides a dense overstory canopy of spruce-fir or mixed conifers, and (3) contains about 15 "good" seed-bearing trees per hectare.

Such species-habitat models are general and approximate. Still, they provide an estimate of what comprises a unit of habitat area and condition that might be required by a squirrel. If a management goal is to provide habitat for X red squirrels then that goal can possibly be achieved by providing X units of good to excellent habitat (fig. 4). The need to provide this quantity of a specific habitat condition should drive management plans for the sub-

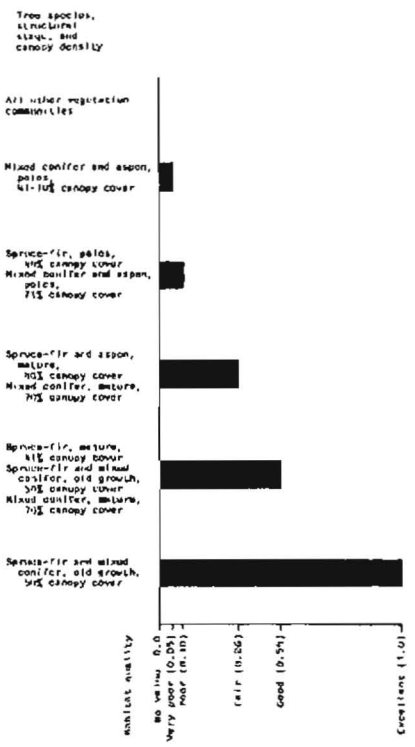

Figure 3.—Habitat quality for the Mount Graham red squirrel can be described in terms of tree species, structured stage, and canopy density within forest habitats. Habitat quality is measured in terms of middens per hectare for different habitats scaled on the basis of 0.0 for no value habitats and 1.0 for excellent habitats. Data from U.S. Forest Service (1988:112).

1. A habitat block suitable for a Mount Graham red squirrel is at least 1 ha in area and is contiguous to other blocks of suitable habitat (fragmentation or isolation totally removes a habitat block from suitability consideration).

   Yes

2. The tree composition of the habitat block is (from Figure 3):

   a. spruce-fir, mature, ≥40% canopy cover
   b. spruce-fir, old growth
   c. mixed conifer, mature, ≥70% canopy cover
   d. mixed conifer, old growth

   Yes

3. The habitat block contains at least 15 "good" bearing spruce-fir or mixed conifer seed trees (a somewhat arbitrary number).

   Yes

   The habitat block provides good to excellent habitat for one Mount Graham red squirrel.

Figure 4.—A word model describing good to excellent habitat condition for a red squirrel.

alpine coniferous forests of the Pinaleno Mountains.

Determine How Human Activities Affect Habitat Conditions Important to the Species

Several human activities and natural events may adversely affect habitats of the Mount Graham red squirrel and reduce the opportunity to achieve the management goal for the species. A listing of possible impacts on the Mount Graham red squirrel and the probable resulting habitat changes is in figure 5.

The cells in a cause-effect matrix (table 1) list estimates of the direction and relative importance of each factor affecting a habitat criterion. The cells within the cause-effect matrix can be completed after synthesizing information from the literature, from best professional judgments elicited from selected personnel or preferably from analyzing results of appropriate research. Information within the cause-effect matrix can indicate the relative importance of different human activities on squirrel habitats and identify actions to be favored or avoided to help achieve the management goal. For example, habitat fragmentation, clearcutting, selective harvest, and forest management favoring early vegetation successional stages are important negative factors to red squirrel habitats whereas management favoring dense, mature or old-growth stands of mixed conifer and spruce-fir forests are important positive actions, favorable to red squirrels. Causes of negative and positive impacts to species or habitats of concern are factors that should be considered when formulating and evaluating plans for modifying habitats important to selected wildlife species.

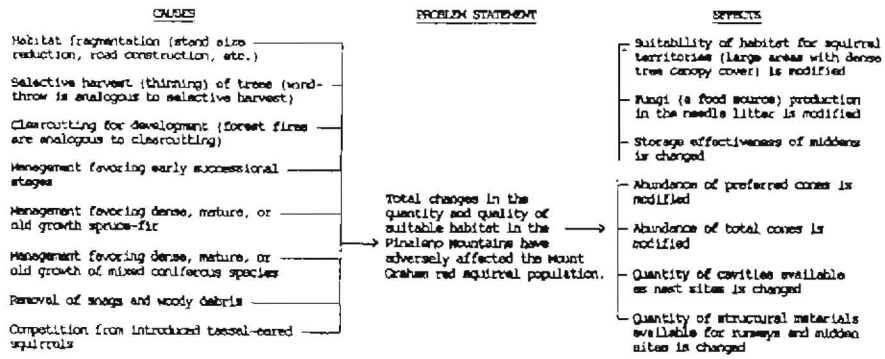

Figure 5.—A cause/effect model identifying causes that affect the quantity and quality of habitat suitable for the Mount Graham red squirrel.

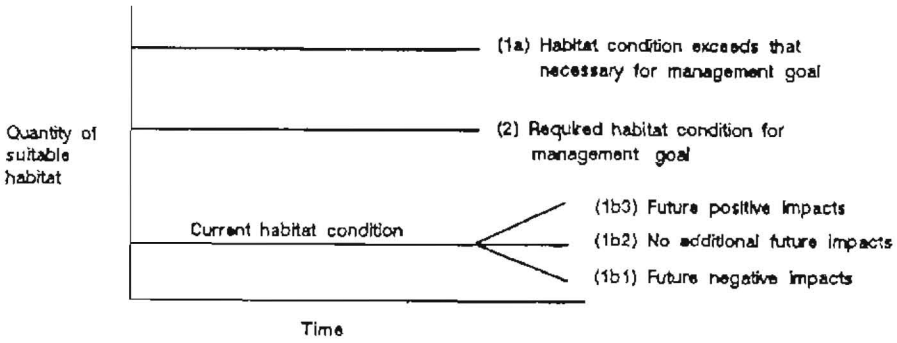

Figure 6.—Habitat conditions under a variety of management strategies.

Solve the Problem

Determine Acceptable Strategies for Managing Habitats Required by the Species

A way to evaluate the diversity of different land-use scenarios is listed in figure 6. Threshold values describing the quantity of suitable habitat necessary for achieving the management goal for the red squirrel can be represented as habitat condition 2 in figure 6. If the quantity of suitable habitat presently available had exceeded this threshold value (condition 1a) then changes to the quantity of available habitat could be tolerated and that fact could be considered in making a decision about a potential land use.

The present quantity of good to excellent habitat for the red squirrel in the Pinaleno Mountains, however, is probably more closely approximated by condition 1b in figure 6. A variety of conditions like those itemized in table 1 have reduced habitat quality and quantity resulting in a diminished squirrel population with an endangered species listing. A land-use plan that continued impacts (like those listed in table 1) would further reduce the area and quality of contiguous blocks of forest habitat important to the squirrel. Any further fragmentation or degradation of habitat would be expected to further diminish the population (1b1 in fig. 6) and perhaps threaten extinction of the subspecies. A land-use plan that neither allowed further degradation of habitat nor actively improved habitat conditions for the squirrel might result in maintaining present population levels (1b2 in fig. 6). The most desirable land-use scenarios are those likely to produce trend lines such as 1b3 (fig. 6). These land-use plans would minimize fragmentation of habitats and would actively man-

age habitats to develop large contiguous blocks of old-growth mixed conifers and spruce-fir on the Pinaleno Mountains to help attain the desired population level of red squirrels.

CONCLUSIONS

We emphasize that potential land-use change can be evaluated in a rational manner if management goals for wildlife resources have been previously established and agreed upon. The merit of this approach is that planning becomes an active rather than a reactive exercise. Too often we evaluate proposed land-use changes in terms of how they might affect present habitats and present populations without considering how present conditions compare to desired populations and necessary habitats. Without establishing a management goal and determining the habitat conditions necessary to achieve that goal, we could accept the wrong baseline for developing our management strategy (perhaps something analogous to line 1b2 in fig. 6). If this occurs, we might have little success in maintaining viable populations because we frequently strive only to

Table 1.—A cause-effect matrix that lists the relative importance of causal agents (causes listed in fig. 4) that change the quantity and quality of habitat features (effects listed in fig. 4) for the Mount Graham red squirrel. A (+) value indicates a positive impact and a (-) value indicates a negative impact. Numerical values indicate the magnitude of an impact: (0) = negligible; (1) = minor; (2) = important; and (3) = very important.

	Suitability of habitat for squirrel territories (large trees with dense tree canopy cover)	Fungi (a food source) production in the needle litter	Storage effectiveness of middens	Abundance of preferred cones	Abundance of total cones	Cavities available as nest sites	Structural materials available for runways and midden sites	Cumulative impact to red squirrels (a summary)
Habitat fragmentation (stand size reduction, road construction, etc.)	-3	-1	0	-1	-1	0	0	-3
Selective harvest (thinning) of trees (windthrow is analogous to selective harvest)	-2	-2	-2	-2	-2	-2	+2	-2
Clearcutting for development (forest fires are analogous to clearcutting)	-3	-3	-3	-3	-3	-3	-3	-3
Management favoring early succession stages	-2	0	0	-2	-2-	3	-1	-2
Management favoring dense, mature, or old growth spruce-fir	+3	+3	+3	+3	+3	+3	+3	+3
Management favoring dense, mature, or old growth of mixed coniferous species	+3	+3	+3	+1	+3	+3	+3	+2
Removal of snags and woody debris	0	0	-2	0	0	-2	-3	-1
Presence of tassel-eared squirrels	0	-1	0	-1	-1	0	0	-1

maintain marginal populations in marginal habitats. A rule for judging the suitability of a proposed land-use change might be that land-use change that can be accomplished while promoting trend lines like 1b3 (with strong positive slopes) or which produce conditions like line 2 in figure 6 are environmentally acceptable and can be accomplished if they are socially and economically desirable.

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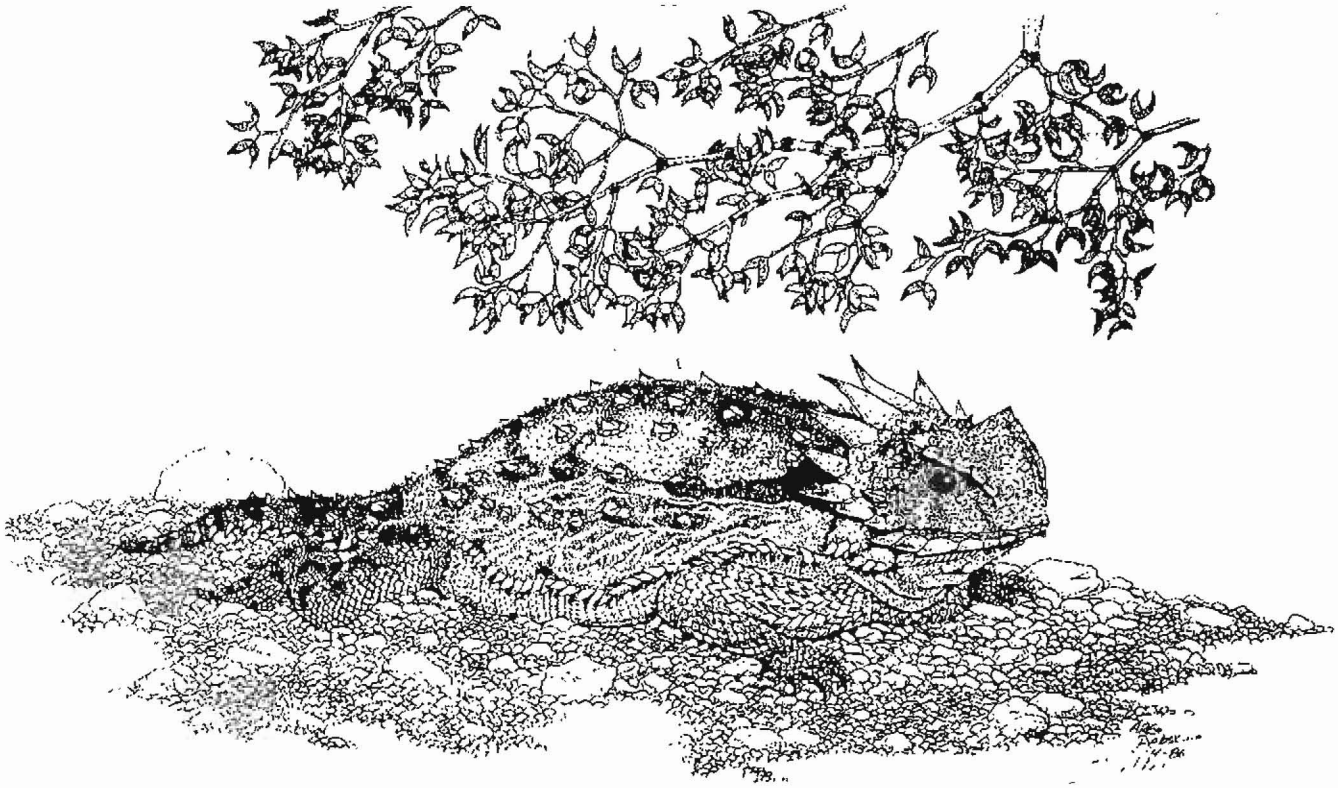

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