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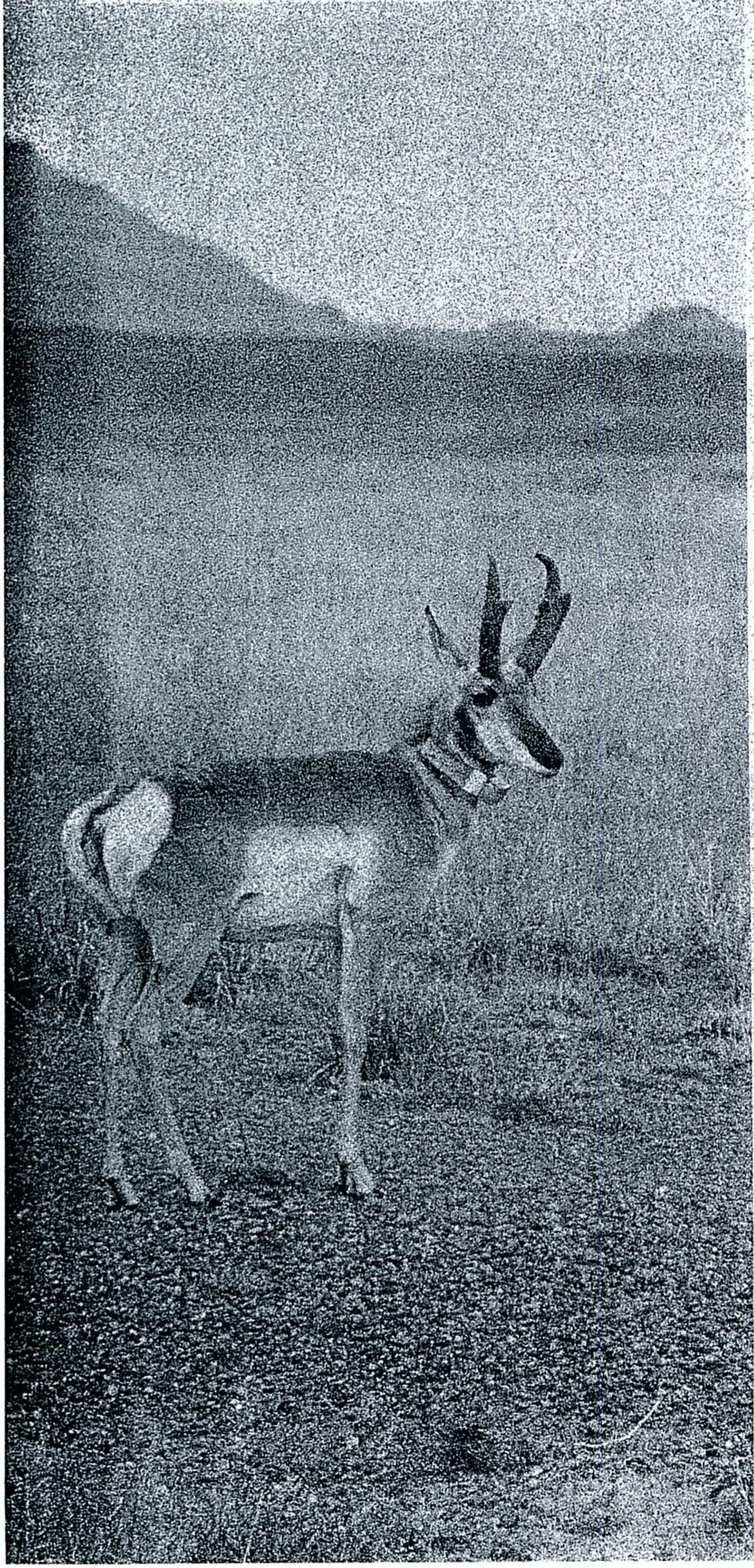

A LANDSCAPE-LEVEL PRONGHORN HABITAT EVALUATION MODEL FOR ARIZONA

A Final Report

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June 1996

FEDERAL AID IN WILDLIFE RESTORATION PROJECT

Arizona Game and Fish Department Mission
To conserve, enhance, and restore Arizona's diverse wildlife resources and habitats through aggressive protection and management programs, and to provide wildlife resources and safe watercraft and off-highway vehicle recreation for the enjoyment, appreciation, and use by present and future generations.

Arizona Game and Fish Department
Research Branch

Technical Report Number 19

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CONTENTS

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In the mid-1980s, biologists Ronald H. Smith and Donald J. Neff conceptualized the idea of a statewide pronghorn habitat evaluation. Neff (1986) did a problem analysis on the subject. Their early efforts and ideas, as well as friendship, are much appreciated. Although both retired before this project materialized, they were an important part of the research process. We appreciate help from William K. Carrel, Brian F. Wakeling, Steven S. Rosenstock, Stan C. Cunningham, and Norris L. Dodd; these co-workers added insight to study design, field sampling, statistical analyses, and report organization.

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A Landscape-level Pronghorn Habitat Evaluation Model for Arizona

Richard A. Ockenfels, Cindy L. Ticer,
Amber Alexander, and Jennifer A. Wennerlund

Abstract: We developed a ground-based, landscape-level rating system to identify and assess pronghorn (*Antilocapra americana*) habitat in Arizona. The rating system works within a Geographic Information System (GIS) based on surveyed sections. Terrain and type of vegetation were the main criteria for determining suitability and relative quality. The availability of water, distribution and structure of fences, and human developments or disturbances were used as modifying criteria. We used 6 habitat quality classes: (1) High with no significant management problems: (2) High with ≥1 management problem, (3) Moderate, (4) Low, (5) Poor, and (6) Unsuitable. To test and validate the system, we captured 84 adult pronghorn in 4 game management units (GMUs) and routinely located them over a 2-4 year period. We first tested the rating system in 2 GMUs where it was developed by using experienced observers. We compared the proportions of the rated habitat to the proportion of pronghorn locations in each habitat quality class to determine if pronghorn used the rated sections more or less than that predicted relative to availability. We then validated the system in 2 northern GMUs by using: (1) the same experienced observers in 1 GMU, and (2) inexperienced observers in another GMU. Based on pronghorn locations, we could identify pronghorn habitat and consistently distinguish between Moderate, Low, Poor, and Unsuitable habitat quality, but determining High quality habitat was difficult. Problems with use of the methodology were: (1) observer subjectivity, (2) scale of evaluation (surveyed sections), (3) labor and time requirements, and (4) private property access. However, the rating system was useful for large-scale, long-term planning efforts.

Key Words: antelope, *Antilocapra americana*, Arizona, assessment, evaluation, habitat, pronghorn, rating system

INTRODUCTION

Neff (1986) described the need for a statewide suitability assessment of pronghorn (*Antilocapra americana*) habitat in Arizona. Based on his work and our appraisal of 9 models for identifying and assessing pronghorn habitat, we present the development, testing, and validation of a new ground-based, landscape-level rating system for Arizona. We also include in this report our assessment of previous models, our final rating system, and photographic examples of rated habitats.

Pronghorn are a species of concern in Arizona. The major problem is continued degradation of pronghorn habitat from such causes as human development, poor livestock fencing structure and densities, shrub and tree encroachment, and highway construction (Fig. 1). Also, pronghorn no longer occupy all their former range in Arizona (Nelson 1925, Ockenfels In Prep.), a situation active management may remedy.

Pronghorn populations in Arizona have been identified and mapped statewide several times since the early 1920s (Nelson 1925, Knipe 1944). They also have been surveyed annually since 1946 by standard aerial methods (Ariz. Game and Fish Dep., unpubl. data). From these surveys, current statewide distribution is well documented. However, the habitat, whether occupied or unoccupied, capable of supporting pronghorn has never been systematically identified and evaluated relative to its quality.

Systematically identifying, mapping, and assessing the relative quality of habitat for pronghorn provides information for long-range planning and can be used to determine likely impacts of human-related activities (Irwin and Cook 1985). Habitat rating systems, or assessment models, are needed to assist such efforts.

Models are used to rate wildlife habitat for a multitude of reasons (Anderson and Gutzwiller 1994). Assessment models can be narrow in scope, specific to a single set of habitat conditions, or they can be general, applicable to many habitats (Anderson and Gutzwiller 1994). Several models have been developed for evaluating pronghorn habitat.

To develop models, habitat requirements for the species must be understood. Habitat requirements for pronghorn have been described for several biomes (Buechner 1950; Yoakum 1974, 1978, 1979, 1980; Autenrieth 1978; Kindschy et al.

Figure 1. Degradation of pronghorn habitat is caused by many factors. Here a fenced highway fragments the habitat. Juniper trees and catclaw are encroaching on the grasslands.

1978, 1982; O'Gara and Yoakum 1992; Ockenfels et al. 1994). Optimum habitat characteristics for pronghorn have been established for sagebrush steppe and prairie grassland habitats (Yoakum 1972, 1974, 1980; Kindschy et al. 1978, 1982), but not for desert (O'Gara and Yoakum 1992), woodland, or forest habitats.

To assess pronghorn habitat on a statewide basis requires a method with broad application appropriate for numerous biomes. An ideal system must be simple, yet accommodate a wide range of habitats. Most models designed to evaluate pronghorn habitat have been specific to the area where they were developed. Application of this model type in different biomes or under conditions other than where it was developed requires caution (O'Gara and Yoakum 1992). For landscape-level planning, assessment models must determine habitat suitability under a wide variety of conditions. Further, habitat assessment models should be tested against measured conditions before they are widely used (Irwin and Cook 1985, Anderson and Gutzwiller 1994).

With these concepts in mind, we first reviewed and appraised a number of evaluation models for statewide applicability in Arizona.

Previous Models

We found 9 models or rating systems that were developed to either identify or assess the relative suitability of habitat for pronghorn. Chronologically, they were:

- A set of criteria used for determining the feasibility of translocation sites in Colorado (Hoover et al. 1959)
- A set of function curves describing optimum habitat for pronghorn in the sagebrush (*Artemisia* spp.) steppe community of the Great Basin (Kindschy et al. 1978)
- A set of guidelines used by U.S. Bureau of Land Management (BLM) to evaluate habitat suitability (Yoakum 1980)
- The U.S. Forest Service (USFS) work sheet rating system for Great Basin sagebrush steppe based on the aforementioned function curves (Kindschy et al. 1982)
- Arizona Game and Fish Department's (AGFD) 1980s guide to prioritize pronghorn transplant sites (Ariz. Game and Fish Dep. 1993)
- The viability index developed for use in domestic sheep pastures by New Mexico State University (NMSU; Howard et al. 1983)
- The winter habitat suitability index (HSI) model by Allen et al. (1984) for the Great Basin sagebrush community
- A set of 9 criteria for evaluating suggested translocation sites in California (McCarthy and Yoakum 1984)
- The U.S. Soil Conservation Service (SCS) evaluation guide for scoring pronghorn habitat in Arizona (U.S. Dep. Agric., unpubl. mimeo. 1989)

Each model had strengths and weaknesses at a landscape level (see Appendix A). We believed a model applicable to Arizona rangelands should:

- Be sufficiently general to work in all possible habitats within Arizona
- Be more than a single subjective ocular estimate or quick drive-through, but not be a research project
- Be on-the-ground, field-oriented rather than assessed by remote sensing methods
- Be compatible with a Geographic Information System (GIS) to provide resource managers with the decision matrix for each area evaluated

Based on these criteria, none of the existing models were appropriate for our needs (see Appendix A). In general, existing models either did not present a wide range within each criterium to chose from, were habitat specific, were only designed to evaluate relative quality within pre-determined suitable habitat, or were data intensive and designed to assess small areas. Further, none were directly compatible with a GIS system. Therefore, we rejected all 9 methods and developed a rating system specific to our needs.

Objectives

Our goal was to develop a rating system to identify and evaluate habitats for pronghorn within large blocks of land (e.g., game management units [GMUs]) in Arizona. Specific objectives were:

- To develop a ground-based, landscape-level rating system to identify and assess the relative quality of pronghorn habitat using GMUs 19A and 21 as pilot areas
- To test the system by using pronghorn telemetry locations within the 2 GMUs as an index of suitability
- To validate the system in GMUs 2A and 7E by using pronghorn telemetry locations as an index of suitability
- To evaluate if level of experience or training needed by field observers affected use of the system
- To develop GIS applications for the database that allow rapid retrieval, subdividing of data, and easy future updating

To meet our objectives, we needed a working definition of habitat quality. Van Horne (1983) interpreted habitat quality as being related to the density of animals present, their likelihood of survival, and the probability of them producing offspring. Although not always true as indicators of habitat quality, these factors certainly are influenced by habitat quality.

Using Van Horne's conceptual definition as a guideline, we designated high quality habitat for pronghorn as: (1) capable of supporting numerous individuals in a given area (e.g., ≥10 adults per 2.59 km² [in our case, each surveyed section, which vary in size, within a township]); (2) having favorable conditions so that annual survival would be high (e.g., >80% adult survival); (3) having favorable conditions so that annual recruitment into the population compensates for adult mortality (e.g., >40 fawns:100 does); and (4) having these conditions stable over a long period of time (e.g, likely to last ≥5 years). Unsuitable habitat would likely meet few or none of these criteria. We also realized that degrees of suitability exist and expected any rating system or model to detect this, rather than merely being able to classify an area as either suitable or unsuitable.

Van Horne's (1983) definition of habitat implied occupancy by animals. Such is not always the case because suitable habitat exists without the presence of animals. Pronghorn have been extirpated from many areas of Arizona (Nelson 1925, Knipe 1944, Ockenfels In Prep). We assume that some of these areas would still support viable pronghorn populations if restocked. The success of future reintroductions is undoubtedly related to the quality and size of available habitat. Therefore, unoccupied as well as occupied habitat needed to be evaluated.

STUDY AREAS

We chose 4 GMUs for model development, testing, and validation: (1) GMU 19A in central Arizona; (2) GMU 21 in central Arizona; (3) GMU 2A in northeastern Arizona; and (4) 7E, the eastern portion of GMU 7, in north-central Arizona (Fig. 2). GMUs 19A and 21 were the development and test areas for our model, whereas GMUs 2A and 7E were the areas used for model validation. These GMUs were chosen because

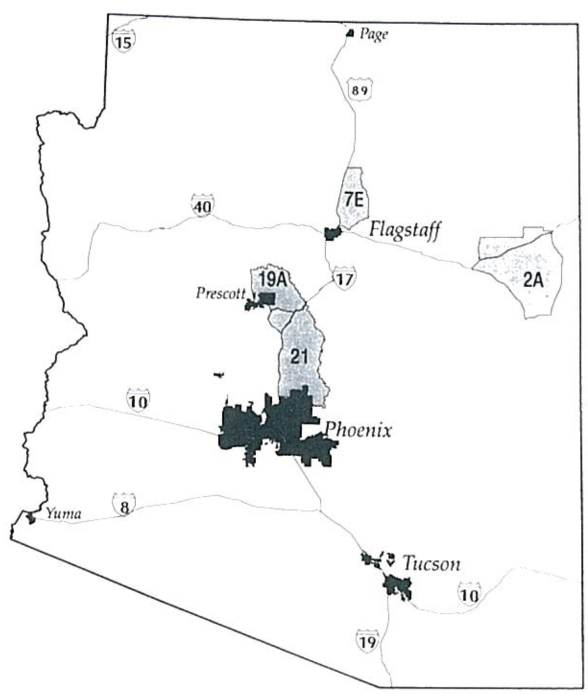


Figure 2. Location of the 4 game management units used to develop, test, and validate the landscape-level pronghorn habitat evaluation model, Arizona, 1989-95.

they contained many of the terrain-vegetation complexes that pronghorn occur in and allowed us to test and validate the model for broader application.

GMU 19A

Within GMU 19A, we selected 3 sub-areas south of Highway US 89A that contained pronghorn populations (Fig. 3). These sub-areas, divided by fenced, primary highways, were designated as: (1) Fain, (2) Orme, and (3) Cherry (see Ockenfels et al. 1994). Elevations ranged from 1,160 m at Cordes Junction to 2,300 m on Mingus Mountain. Terrain along the eastern edge (Orme) was hilly to semi-mountainous; the middle (parts of all 3 sub-areas) was mainly hilly; along the northern edge (Cherry), it was semi-rugged mountainous; and along the western edge (Fain), undulating terrain was predominant. The only major waterway was the Agua Fria River, which was normally dry, except during periods of substantial precipitation.

Because of the range in elevation and terrain, these sub-areas had a myriad of vegetational types, including plains grassland (i.e., short-grass prairie; only in Fain), semidesert grassland, Great Basin conifer woodland, and interior chaparral (Brown 1994). Within the plains grassland on the Fain area, grama (*Bouteloua* spp.) and ring-grass muhly (*Muhlenbergia torreyi*) predominated. Scattered shrubs, cacti, and succulents were components of the vegetation; cholla (*Opuntia* spp.) and beargrass (*Nolina microcarpa*) were the most noticeable species. Interior chaparral species, mainly shrub live oak (*Quercus turbinella*), occurred on north-facing slopes in the grassland near the foothills of Mingus Mountain. Plant names throughout follow Lehr's (1978) modification of Kearney and Peebles (1960).

In the semidesert grassland, tobosa (*Hilaria mutica*) was the dominant grass, although its dominance was shared with a variety of shrubs, cacti, and succulents. Shrub-form mesquite (*Prosopis juliflora*), catclaw (*Acacia greggii*), broom snakeweed (*Gutierrezia sarothrae*), Wright's buckwheat (*Eriogonum wrightii*), *Opuntia* spp. (prickly pear cactus and cholla), and yucca (*Yucca* spp.) were the most abundant.

Shrub live oak, squaw bush (*Rhus trilobata*), red barberry (*Berberis haematocarpa*), ceanothus (*Ceanothus* spp.), and hollyleaf buckthorn (*Rhamnus crocea*) formed thickets of medium-height vegetation in the interior chaparral habitat. Manzanita (*Arctostaphylos* spp.) and silk tassel (*Garrya flavescens*) were also present in some areas.

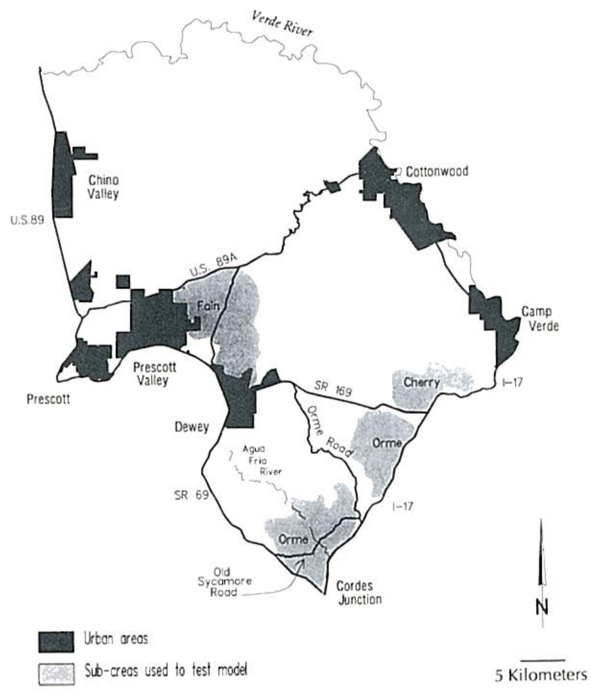


Figure 3. Sub-areas within Game Management Unit 19A used to develop and test the landscape-level pronghorn habitat evaluation model, Arizona, 1989-95.

Much of the interior chaparral was dense enough to restrict large mammal movements. Within the interior chaparral, only riparian areas typically changed the landscape. In some areas, interior chaparral occupied the northerly slopes, whereas grasslands occurred on the southerly slopes.

Great Basin conifer woodlands were predominantly juniper (*Juniperus* spp.), with some pinyon pine (*Pinus edulis*) present. Canopy closure ranged from a savanna-like condition to closed areas exceeding 50% cover. Junipers encroached into grasslands bordering either woodlands or chaparral.

GMU 21

We selected the northern half of GMU 21, from Black Canyon City (630 m) north to the Verde Rim. Most of the area was between 900-1,200 m in elevation. The topography of GMU 21 was typically more rugged than the sub-areas in GMU 19A. Here, waterways such as the Agua Fria River, Sycamore Creek, Yellowjacket Creek, Ash Creek, Little Ash Creek, Silver Creek, and Squaw Creek were steep-walled canyons that separated the flats or rolling hills into mesas.

The area was mainly semidesert grassland or Great Basin conifer (juniper) woodland. Three large grassland areas were present: East Pasture, Marlow Mesa, and Perry Mesa. The eastern edge of the area was mainly dense juniper woodland or interior chaparral. Riparian deciduous forests lined the waterways. The Arizona upland division of the Sonoran desertscrub (Brown 1994) occurred below 900 m along the study area's southern boundary.

GMU 2A

We selected the portion of GMU 2A that centered on Petrified Forest National Park (PFNP), ranging eastward to the Navajo Nation boundary (Navajo Road 7001) and Highway US 191, westward to Holbrook, and north-south from I-40 to US 180. Most of the area was undulating to rolling hills terrain. Elevation was uniform throughout, mostly between 1,650-1,800 m. Small steep-walled mesas rose above the plains. The Puerco River was the only major waterway, but it was not deeply-incised. Within and around PFNP, much of the landscape had barren, heavily eroded hills.

GMU 2A contained 2 sub-areas: (1) the area between I-40 and the fenced Atchison, Topeka, and Santa Fe (AT&SF) railroad right-of-way (Fig. 4); and (2) the area south of the fenced railroad right-of-way to US 180.

Great Basin grassland (Brown 1994) and Great Basin conifer (juniper) woodland dominated the landscape. The predominant grasses were blue grama (*B. gracilis*) and alkali sacaton (*Sporobolus airoides*). Shrubs formed small thickets, comprised of such species as sagebrush (*Artemisia* spp.), salt bush (*Atriplex* spp.), rabbit brush (*Chrysothamnus* spp.), and joint-fir or Mormon-tea (*Ephedra* spp). Snakeweed was also abundant in localized, poorer condition sites.

GMU 7E

We selected the area of GMU 7 east of Highway US 89 (7E), from Cameron south along the Navajo Nation boundary to Forest Road (FR) 505, then west on FR 505 to FR 510, then west on FR 510 back to US 89. This southern boundary is commonly called the Townsend-Winona-Leupp Road.

This area was centered on Wupatki-Sunset Crater National Monuments (WNM). Elevation ranged from 1,350 m in the Little Colorado River (LCR) drainage near Cameron to 2,700 m on O'Leary Peak.

Terrain varied considerably in this study area. Most of the northern portion of the study area was undulating to rolling hills, with the exception of an escarpment from the community of Gray Mountain to Black Point, a prominent mesa overlooking the LCR. This escarpment continued south from Black Point as a bluff of the LCR, which was moderately incised along most of the eastern study area boundary. A series of volcanic mountains arose in the center of the area, comprising the Sunset Crater field. In the south, the volcanic field was more broken, and flats were more prevalent.

The northern portion of the area was mainly plains grassland, which was dominated by *Hilaria* spp. and alkali sacaton; some prairie clearings were heavily invaded with rabbit brush. Great Basin woodland occupied most of the middle and eastern edge of the area, whereas Rocky Mountain conifer forest (ponderosa pine [*P. ponderosa*]; Brown 1994) extended throughout much of the volcanic field. Cliff rose (*Cowania mexicana*) and Apache plume (*Fallugia paradoxa*) formed dense stands in localized areas.

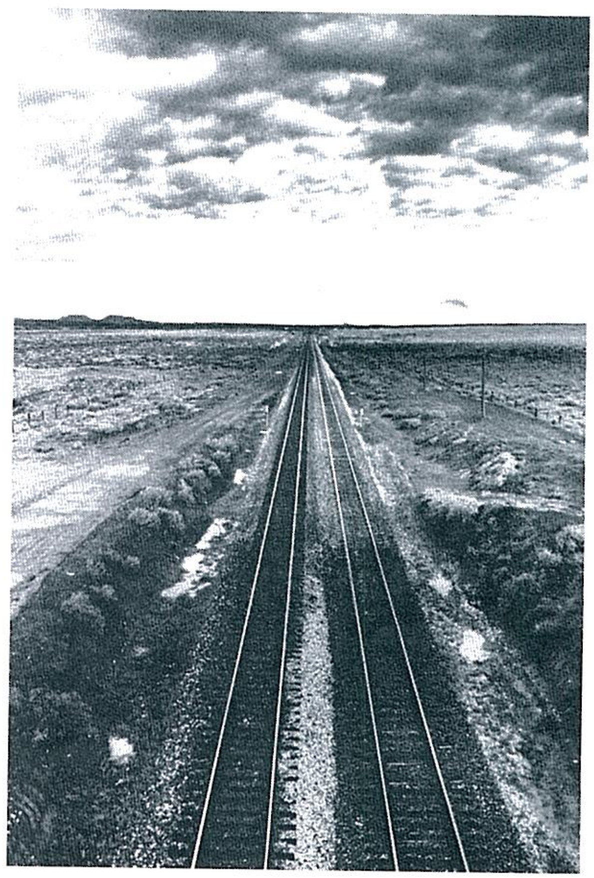


Figure 4. The Atchison, Topeka, & Santa Fe railroad right-of-way was a movement barrier dividing Game Management Unit 2A into 2 sub-areas to validate the landscape-level pronghorn habitat evaluation model, Arizona, 1989-95.

METHODS

Model Development

Topographic ruggedness, vegetative structure and species richness, and water availability were key elements in existing evaluation models (Fig. 5; Appendix A). These 3 factors were the foundation for assessing pronghorn habitat, regardless of whether the model was time or area specific. Although each model appraised these factors in a different manner, all seemed plausible in explaining the relative suitability of an area for pronghorn.

However, we found no existing model or rating system appropriate for evaluating pronghorn habitat at a statewide landscape level. The reasons for that were: (1) existing models were not GIS compatible, (2) they tended to be specific to a single habitat (e.g., sagebrush steppe), (3) they tended to be time specific (e.g., winter, spring), or (4) data collection was too intensive.

GIS System. We could have modified some existing models to be GIS compatible by specifying a small area for resolution. To do so, we could have constructed a statewide grid system based on a km² or any small unit of the State Plane or Universal Transverse Mercator (UTM) coordinate systems. However, no statewide map systems were delineated so that we could have easily and quickly identified field positions, nor was a statewide GIS database readily available based on such coordinate systems.

Several existing models were general enough to use at a landscape level. These could have been adapted for use with the Township-Range-Section (TRS) GIS database at the Arizona State Land Department. This system was digitized directly from survey lines on a variety of map sources (U.S. Geological Survey [USGS] 7.5′ [1:24,000] and 15′ [1:62,500] topographic maps, USFS 1:126,720 forest maps, and BLM 1:100,000 land surface maps). However, these models had other features that were incompatible with our objectives.

Because of its GIS advantages, we chose the TRS database as our starting point for model development. Each surveyed section (typically but not always 2.59 km²) was our experimental unit. Within TRS, alternative choices would have been to evaluate a township (typically 36 sections or 93 km²) as the unit area or construct a new statewide coverage. A township was deemed too large an area to accurately reflect the heterogeneity of habitats and terrains throughout Arizona. Constructing a new statewide coverage was deemed too time consuming and costly. A relatively small portion of the state had not been surveyed, so no TRS grid existed. In these cases, we would have to create our own GIS grid of pseudo-TRS lines.

Figure 5. Terrain ruggedness and vegetational characteristics are the key factors that determine habitat suitability for pronghorn. Here, conditions were suitable for pronghorn.

Vegetational Classes. By using the TRS database, we could work in any habitat. To prevent being habitat specific, but still be simple enough to use over a statewide basis, we chose the formation level (i.e., woodland, forest, grassland, scrub, desertscrub; Brown 1994) as our model starting point. We then broke each formation into 16 classes based upon vegetational structure and species richness (Appendix B).

Forb cover, a key component because of its importance in pronghorn diets, is most accurately evaluated during the spring or summer. However, time constraints in a statewide evaluation effort would necessitate field crews evaluating habitat year round. Removing forb cover assessment weakens any model developed for pronghorn. Nonetheless, by assessing perennial grasses, shrubs, succulents, trees, and percent bare ground, we believed we could identify and roughly evaluate the relative quality of any area to support a pronghorn population. Since our intent was to identify, assess, and directly compare habitats across the state in a short period of time, achieving an accurate assessment of forb cover was unobtainable.

Lastly, we divided the model's 16 vegetational classes into 6 quality classes. We used the following 6 overall ratings (Appendix B):

- High quality without significant management problems
- High quality, but the area has ≥1 management problem that could be mitigated
- Moderate quality
- Low quality
- Poor quality
- Unsuitable quality, will not support pronghorn

Terrain Classes. Another key factor that typically influences pronghorn use of an area is terrain ruggedness (Yoakum 1974). Pronghorn typically select gentle terrain and avoid rugged areas. Terrain ruggedness is influenced by the heterogeneity of slopes and the substrates present. As a starting point, we chose to identify areas by percent slope measurements in 10% increments.

Because of the increased likelihood of mountain lion (*Felis concolor*) predation on pronghorn in areas close to steep-walled canyons (Ockenfels 1994), we incorporated this parameter into our rating system. In addition to the actual terrain, distance to a steep-walled canyon was a factor in the terrain classes.

We used 10 classes of terrain (Appendix B). As with the vegetational classes, we subdivided terrain classes into the 6 overall habitat quality classes.

Other Factors. Human-related activities modify the relative suitability of habitat for pronghorn. Water sources built for livestock also provide water for pronghorn, if fences do not obstruct access. Conversely, reliable water sources may increase predator densities. Accurately assessing year-round water availability from a single visit is unrealistic. However, we could still provide a rough estimate of the availability of natural and constructed water sources.

Livestock fencing adversely impacts pronghorn (O'Gara and Yoakum 1992). The type and density of fences influences pronghorn habitat use and movement patterns. By assessing livestock fences, we could roughly estimate whether the suitability of an area to support pronghorn had been compromised. Human disturbances lessen the likelihood that pronghorn use or move through an area. By estimating the amount of development or disturbance that would occur in a section, we could estimate whether suitability had been reduced or totally compromised.

To assess these factors, we designated classes for the following categories: (1) water distribution and availability, (2) fence structure and distribution, and (3) the amount of human development or disturbance potential within each surveyed section. As with the vegetational and terrain classes, we divided the classes within these evaluation categories by habitat quality (Appendix B).

Capture and Location

We captured adult pronghorn with a net-gun fired from a helicopter (Firchow et al. 1986) in mid-October from 1989-92. The exception to this pattern was a capture in mid-March. Pronghorn were radio equipped, ears tagged, and released at the capture site (Fig. 6).

Figure 6. Adult pronghorn were captured with a net-gun, radio collared, and located over 5 years to develop, test, and validate the landscape-level pronghorn habitat evaluation model, Arizona, 1989-95.

We located the pronghorn 1-2 times per week for most of 1989-92 in GMUs 19A and 21. During 1992-94, location efforts were reduced to 2-3 times per month in GMUs 2A and 7E. We used various modified high-wing, single engine aircraft for aerial locations. Each aircraft had a forward oriented, phased, twin Yagi antenna system mounted on the wing struts for signal detection and general signal direction, and a rotatable, belly-mounted H-antenna used to pinpoint animal locations (Carrel 1972*a*,*b*). During each flight, we plotted the locations on 7.5′ USGS topographic maps. We then derived UTM coordinates to the nearest 0.1 km.

We encoded all locations into computer databases, verified the data, converted the data to ASCII format, and transferred the UTM-coordinate files into GIS (ARC/INFO®) overlays for the 4 study areas.

Field Maps

We scaled our maps to 1:100,000 to correspond with existing mapping systems. We used 3 maps for each GMU: (1) a vegetational and slope analysis to determine potential areas to assess, (2) a landownership map, and (3) a scanned image of either USGS or BLM 30 *x* 60-minute (1:100,000) maps overlaid with a TRS grid.

Vegetation-slope Maps. For vegetation, we used a statewide map produced in 1977 (updated in 1980s) by AGFD Wildlife Managers, who mapped vegetation in their individual GMUs following a digitized computer-compatible classification scheme at the biotic community level (Brown and Lowe 1974). These maps were available in digital format. We simplified the overlay from the biotic community back to the formation level by combining related communities. For example, all grassland communities were lumped into the grassland formation.

Because pronghorn avoid dense, tall vegetation that restricts their visibility (Sundstrom et al. 1973; Yoakum 1974, 1979; Autenreith 1978; Hailey 1979; Kindschy et al. 1982; O'Gara and Yoakum 1992; Ockenfels et al. 1994), we deleted from consideration areas mapped as dense mixed-conifer forest, interior chaparral, and riparian for each GMU; we did this deletion with the GIS. We selected grasslands as the key habitat to evaluate, then arbitrarily put a 3.2-km buffer around each grassland polygon with the GIS; these buffers contained areas mapped as desert, woodland, or coniferous forest. Buffers were used because ecotones along grassland boundaries often have less dense shrub or tree cover and could provide additional habitat for pronghorn.

Using an existing statewide USGS Digital Terrain Elevation Database (DTED; with 90-m intervals), we calculated slope in 10% classes for the entire GMU. Next, we removed from consideration any areas with slopes >20% to eliminate large areas of rugged terrain, such as mountains and steep-walled, deeply-incised canyons, from field evaluation.

We overlaid TRS lines with the vegetation-slope file. We plotted the final vegetation-slope map for each GMU at 1:100,000 scale. We then prepared a corresponding list of USGS 1:24,000 topographic maps within the GMU for the field crew to use.

Landownership Maps. To determine ownership status and respect private property rights, we needed landownership field maps. The Arizona State Land Department maintained a GIS landownership status cover. From this cover, we extracted each GMU and overlaid the TRS cover. We plotted the final landownership map for each GMU at 1:100,000 scale. We gained written permission to access private property and sensitive management areas (i.e., national monuments and parks).

Scanned Image-TRS Maps. USGS or BLM 30 *x* 60-min (1:100,000) maps were scanned into Tag Image File (.TIF) format with a black-and-white 400-dots-per-inch image processor. The "*.TIF" files were registered and rectified to the UTM coordinates of the 30 *x* 60-min map sheets for image-to-world transformation. We then overlaid the TRS cover on the image file for each GMU. Lastly, we plotted the final image map at 1:100,000 scale. These maps were used to plot allotment boundaries and maintain a record of which sections were evaluated.

Data Collection

Experimental Design. Our experimental design used 2 teams to assess habitat: 1 with experienced personnel in pronghorn habitat assessment (Team 1) and the other without previous pronghorn habitat assessment experience (Team 2). We field tested the rating system in GMUs 19A and 21, where the system was developed. Team 1 completed the field tests because they were part of the development team and documented many of the pronghorn habitat use patterns in the 2 GMUs.

For validation, Team 1 evaluated GMU 2A, an area where they were only slightly familiar. Team 2 evaluated GMU 7E; they were unfamiliar with the area. To estimate observer bias, Team 1 also evaluated GMU 7E, an area unfamiliar to them.

To determine the effort necessary to evaluate a GMU, we recorded the number of hours expended each day on field evaluation within the GMU, including travel, note taking, and summary time. Our rough measure of effort was the mean number of surveyed sections evaluated per hour; for each GMU, we divided the total number of sections evaluated by the sum of all hours expended.

For surveyed sections that we had authority or permission to enter, we attempted to drive through each that the vegetation-slope map indicated as potential pronghorn habitat. As we traveled, we noted the occurrences and locations of fences, waters, roads, railroads, and buildings in or near the section. We scanned from high points to improve our visibility of the section or to rate sections inaccessible by vehicle. We had to hike to some high points.

Evaluating Terrain. We ocularly scanned the general terrain features for the section being evaluated, compared it to the map contour patterns on either 1:24,000 or 1:62,500 scale USGS topographic maps, and rated it into 1 of 10 possible classes (Appendix B). The topographic maps also aided us in evaluating terrain in areas that were not visible from the road or easily reached on foot. To aid in estimating percent slope in the field, we used a clinometer to periodically check our visual estimates; on the maps, we used a standard slope-class indicator template.

Evaluating Vegetation. For vegetational classes (Appendix B), we ocularly appraised the relative density (percent canopy cover) of trees. To assist with estimating tree density, we used a SCS visual guide to percent cover as a means of reducing observer bias (U.S. Dep. Agric., unpubl. rep. M7-L-299). We also evaluated grass, shrub, and bare ground components. Forbs were not evaluated because of their ephermal nature. We subjectively categorized the richness of each plant category within the section and rated the vegetation over most of the section into 1 of 16 possible classes (Appendix B).

Evaluating Other Factors. Using our notes on the presence, usage, and number of buildings and roads, we estimated the relative amount of human disturbance (from 7 possible classes) within each surveyed section (Appendix B). Next, the presence, structure, and density of livestock fences within or surrounding the section were ocularly appraised. One of 7 fencing classes was selected as representative of the section (Appendix B). Lastly, we rated the distance to possible water sources that pronghorn in that section would have to travel, choosing from 4 possible classes (Appendix B).

Adding Information-only Data. We collected additional data to give resource managers better insight into the quality of habitat that each surveyed section provided for pronghorn. We estimated the likely seasonal use of the section as either year-round, summer, or winter-only range (Appendix B). The juxtaposition of the High or Moderate quality pronghorn habitat in each section to similar quality habitat was assessed (Appendix B). Lastly, the factor that was the most critical management problem to deal with in that section was recorded (Appendix B). These categories were not used in determining the overall suitability rating for the section.

Determining An Overall Rating. An overall rating, from 6 possible classes (Appendix B), for each section was then estimated using the ratings for the 5 aforementioned evaluation categories (terrain, vegetation, development-disturbance, fencing, and water). Terrain and vegetation categories had the greatest influence on the overall rating.

To receive an overall rating of 1, the highest quality habitat, both terrain and vegetation had to receive either a 1 or 2 and all other categories had to have a rating of 1. For the rest of the overall ratings, different combinations of ratings occurred (Appendix B).

The initial score was based on terrain and vegetation. If any of the other categories rated ≥ 5 and the initial overall rating was <4 (i.e., High or Moderate), then the overall score was lowered 1 in value to reflect the lower quality of an area due to modifying factors. For example, a class 3 (Moderate quality) section based on terrain and vegetation would drop to a class 4 (Low quality) if fencing structure and density was of a nature to impede pronghorn use of the area. If any category was rated in the Unsuitable class, the overall rating automatically dropped to Unsuitable quality.

Data Analysis

Data Preparation. After data collection in a GMU, we sorted the data sheets by township and range, then encoded the records into a SPSS/PC® database. Frequency distributions of the variables were plotted to identify substantial errors, which we then corrected. We printed the data, verified against the original data sheets, and corrected the files.

We sorted the corrected file records by township, range, and section, and calculated a 10-digit GIS-compatible TRS code for each record. Lastly, we transformed the datafile from SPSS system format into ASCII format and transferred it into the UNIX-based GIS.

GIS Overlay. We developed GIS covers of pronghorn locations by transferring ASCII data files to the GIS for each study area. These files generated GIS point covers of all pronghorn locations for each study area. Associated attributes were related by a unique number for each location and their x and y coordinates. The resultant point covers were then used for all analyses.

For the habitat evaluation data, a similar process was followed. The field codes were related to the existing TRS database in the GIS for each GMU. Attributes (field codes) were appended to the TRS database.

We calculated the areal extent (km^2) of each overall habitat quality rating within each GMU sub-area by overlaying a sub-area cover to the habitat quality cover. Next, we calculated the proportions of each areal extent relative to its sub-area, as a measure of habitat availability. We used overlay analysis in the GIS to compare pronghorn locations and the evaluated habitat in each GMU sub-area. For testing purposes against telemetry locations, only those sections accessible to radio-collared pronghorn in either Fain, Orme, or Cherry were used. We tested each of these sub-areas separately.

After overlaying the locations with the evaluated habitat, we totalled the number of locations in each overall habitat class for each sub-area. We then calculated the proportion of locations within each habitat quality rating for each sub-area as the measure of pronghorn use.

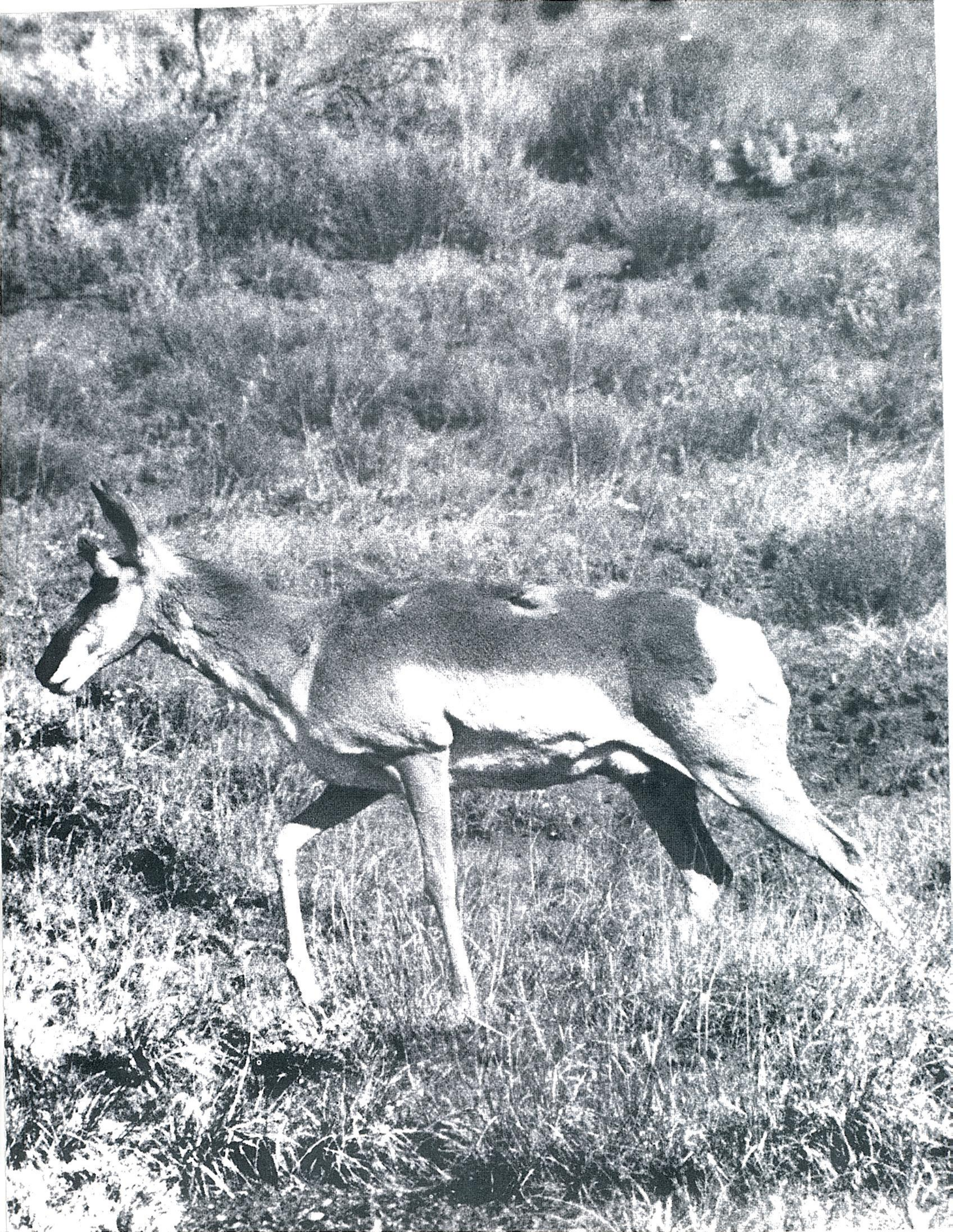
Testing Rating Effectiveness. For each GMU sub-area, we compared the proportion of locations in each overall habitat rating class with the proportion of the study area in each overall rating class by chi-square contingency table analysis (Zar 1984). We used contingency tables rather than goodness of fit analysis because we only estimated the expected distribution (Thomas and Taylor 1990). To ensure proper chi-square analysis, we lumped the data until all expected cell totals had >1 location and <20% of the expected cells had <5 locations (Zar 1984:49).

If contingency tables indicated a significant difference between the 2 distributions, Bonferroni simultaneous confidence intervals were calculated to determine which rating classes were selected or avoided (Neu et al. 1974, Byers et al. 1984). If selection or avoidance was detected for a cell, we calculated a Jacobs' D to indicate the direction and magnitude of non-random use for that rating score (Jacobs 1974).

Observer bias. We calculated Jacobs' D values for both Teams 1 (experienced team) and 2 (inexperienced team) for GMU 7E to determine if overall scores resulted in a similar pattern of selectivity. We also constructed an error matrix of overall ratings between Teams 1 and 2.

In the matrix, Team 2 was used for the initial score, then we determined Team 1 scores relative to Team 2, assuming that the experienced Team 1 scores would have a greater probability of reflecting habitat quality than inexperienced Team 2. To assess the inter-team reliability or relatedness of the 2 teams scoring a section, we used Kendall's coefficient of concordance W (Zar 1984:352). In our test, Kendall's concordance W was a measure of agreement between independent raters assessing the same sections. Kendall's W ranges from 0 (no agreement) to 1 (total agreement).

Lastly, we calculated the numerical difference between team scores for each section. We then produced a frequency distribution of the magnitude of differences in overall rating between the 2 teams.



RESULTS

Capture and Location

We radio equipped and ear tagged 84 adult pronghorn between October 1989 and October 1992. Most locations we took were between 0500 and 2000 Mountain Standard Time (MST).

GMU 19A. We located 18 (11♀ and 7♂) pronghorn between October 1989 and October 1993 (Fig. 7). In Fain, we located 4♀ and 2♂ 795 times; in north and south Orme, we located 4♀ and 3♂ 1,054 times; and in Cherry, we located 3♀ and 2♂ 571 times. No pronghorn in 19A were ever located in more than 1 of the 3 major sub-areas.

GMU 21. Between October 1989 and October 1993, we located 29 (18♀, 11♂) pronghorn 2,582 times (Fig. 8). Many of the pronghorn used both the northern and southern portions of GMU 21 (Ockenfels et al. 1994).

GMU 2A. We radio equipped and ear tagged 15♀ and 5♂ pronghorn during October 1992 and located them until October 1994 (Fig 9). Of the 20 captured, we captured 4♀ in the small sub-area north of the railroad right-of-way, which we located 385 times; for the larger southern sub-area, we located 11♀ and 5♂ 1,351 times.

GMU 7E. In October 1992, we captured 13♀ and 4♂ pronghorn. Between October 1992 and October 1994, we located these 17 adults 1,701 times, of which 1,671 were located within the GMU boundary (Figs. 10, 11).

Habitat Evaluation

GMU 19A. Field maps were prepared for GMU 19A during late April 1994. Team 1 field evaluated GMU 19A during 12 days of May 1994 and re-assessed portions of it in 2 days of October 1994. Of the 1,958 km² available in GMU 19A, they assessed 533 surveyed sections (1,232 km²), averaging 4.5 sections rated per hour. The rest of the unit, as indicated by our GIS mapping, was either too rugged for pronghorn or was dense, interior chaparral habitat that did not need evaluation. Very little of the GMU was rated as High for pronghorn, however, much was acceptable (predominantly Moderate or Low) habitat (Fig. 7).

In GMU 19A, 73.3% of the pronghorn locations occurred in sections rated as either High, Moderate, or Low quality classes that contribute to supporting populations of pronghorn. Thus, we could identify reasonably well pronghorn habitat in GMU 19A by rating surveyed sections.

All possible overall habitat ratings occurred in the Fain sub-area. Non-random (χ^2 = 750.87, df = 3, n = 795, P < 0.001) use of the sections by pronghorn occurred between 1989-92 (Table 1). In general, sections that were rated High or Moderate were the sections that pronghorn used above availability, whereas those sections rated as being either lower in quality or Unsuitable were used less than available. We could not be sure we correctly identified High quality areas (rated a 1 or 2), as the Jacobs' *D* selectivity indice was not greater than that of the Moderate class. Overall, we subjectively judged the performance of the rating system to be good in the Fain sub-area.

In the Orme sub-area, there was no High quality pronghorn habitat (rated 1 or 2). As with the Fain sub-area, non-random (χ^2 = 522.50; df = 2; n = 1,054; P < 0.001) use occurred (Table 1). Because of the small size of this sub-area, the small amount of Moderate quality habitat available, and the complete lack of High quality habitat available, we found that the pronghorn had to use surveyed sections that were lower in quality than those in Fain. However, they selected the best available to them. As with the Fain area, pronghorn showed nearly total avoidance of the areas we mapped as Unsuitable; in this sub-area, most Unsuitable sections were dominated by dense interior chaparral. We subjectively judged the performance of the rating system to be fair in the Orme sub-area.

Similar to the Orme sub-area, there were very few contiguous blocks of good habitat in the Cherry sub-area, thus no surveyed sections were rated as either High or Moderate. Without the availability of better quality contiguous habitat, adult pronghorn selected (χ^2 = 700.49, df = 2, n = 571, P < 0.001) those sections that contained some better quality habitat, that we rated the best available, and showed nearly total avoidance of the Unsuitable sections (Table 1). Much of the Unsuitable area was predominantly rugged mountain terrain with a dense, interior chaparral or woodland cover. In our opinion, the rating system only worked fair in the Cherry sub-area.

GMU 21. Field maps were prepared for GMU 21 during May 1994. Our GIS efforts indicated most of the GMU was rugged terrain covered with dense woodland, desert, or interior chaparral vegetation that precluded field assessment. Team 1 evaluated 358 surveyed sections (818 km²) during 4 days of May, then verified the rated areas in December 1994. The number of sections rated per hour (4.0) was slightly less than that for GMU 19A. Two substantial areas of suitable pronghorn habitat were identified (Fig. 8).

We could identify reasonable quality

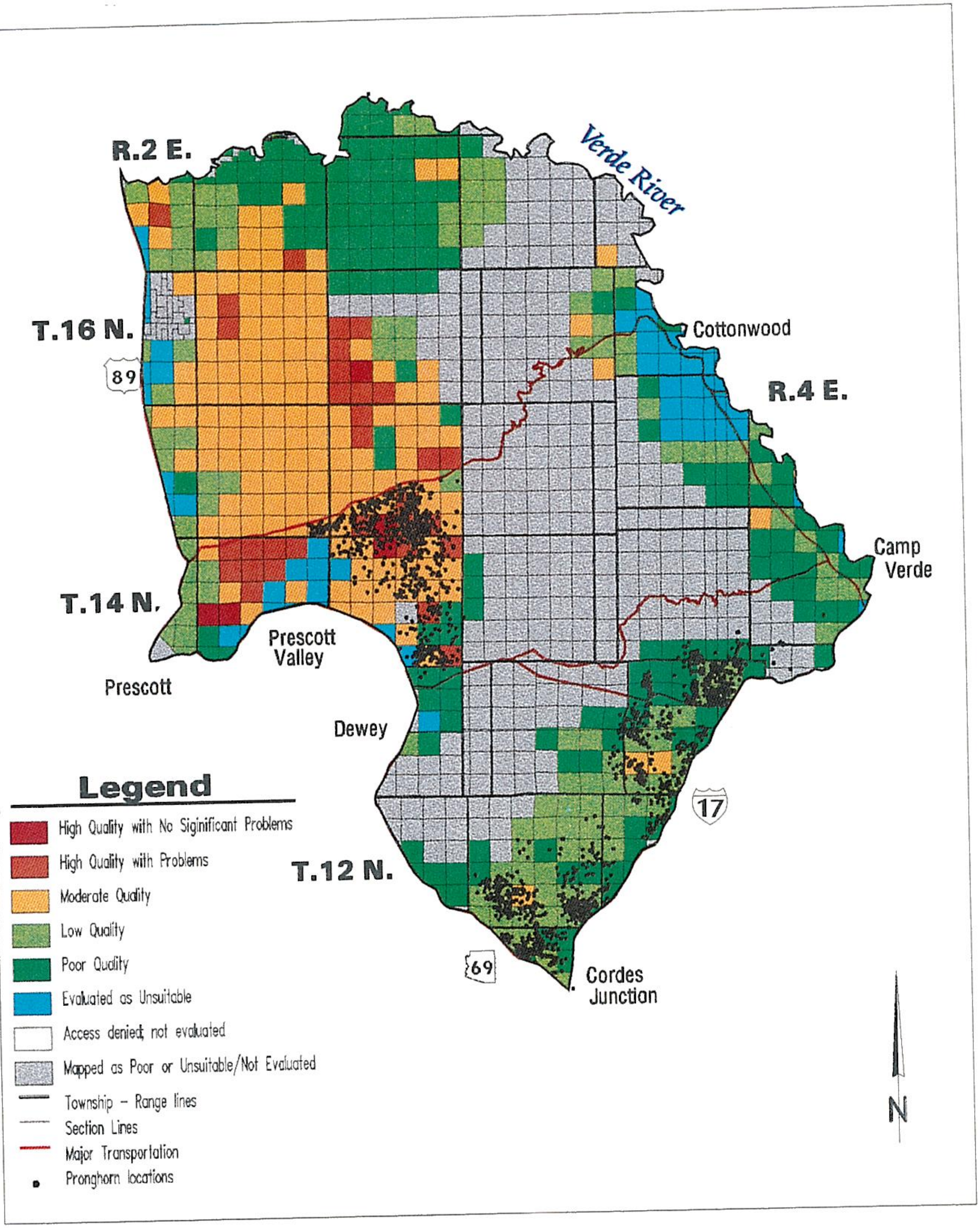


Figure 7. Habitat rating of Game Management Unit 19A overlaid with pronghorn locations, Arizona, 1989-95.

Table 1. Pronghorn use[a] of habitat rated by model within Game Management Unit 19A, central Arizona, 1989-95.

Fain

Habitat quality	No. of locations	% of locations	Bonferroni 90% CI	km² available	% of area	No. of locations expected	Jacobs' *D*
High/no problems	48	6.04	3.97 - 8.11	5.05	1.56	12.7	0.60
High/problems	292	36.73	32.54 - 40.91	20.38	6.44	51.2	0.79
Moderate	405	50.94	46.60 - 55.28	66.58	21.04	167.3	0.59
Low	2	0.25	0.00 - 0.68	2.19	0.69	5.5	-0.48
Poor	32	4.03	2.32 - 5.74	22.94	7.25	57.6	-0.30
Unsuitable	13	1.64	0.54 - 2.74	13.58	4.29	34.1	-0.46
Mapped unsuitable	3	0.38	0.00 - 0.91	185.74	58.69	466.6	-0.99
	795	100.01		316.46	99.96	795.0	

Orme

Habitat quality	No. of locations	% of locations	Bonferroni 90% CI	km² available	% of area	No. of locations expected	Jacobs' *D*
High/no problems	0	0.00		0.00	0.00		
High/problems	0	0.00		0.00	0.00		
Moderate	65	6.17	4.44 - 7.90	8.21	2.37	25.0	0.46
Low	651	61.76	58.27 - 65.25	117.03	33.78	356.1	0.52
Poor	338	32.07	28.72 - 35.42	86.18	24.88	262.2	0.18
Unsuitable	0	0.00		2.58	0.74	7.8	-1.00
Mapped unsuitable	0	0.00		132.43	38.23	402.9	-1.00
	1,054	100.00		346.43	100.00	1,054.0	

Cherry

Habitat quality	No. of locations	% of locations	Bonferroni 90% CI	km² available	% of area	No. of locations expected	Jacobs' *D*
High/no problems	0	0.00		0.00	0.00		
High/problems	2	0.35	0.00 - 0.93	1.27	0.47	2.7	
Moderate	0	0.00		0.41	0.15	0.9	
Low	312	54.64	49.79 - 59.49	13.90	5.16	29.4	0.91
Poor	249	43.61	38.77 - 48.44	48.43	17.96	102.6	0.56
Unsuitable	0	0.00		0.00	0.00		
Mapped unsuitable	8	1.40	0.25 - 2.55	205.59	76.26	435.4	-0.99
	571	100.00		269.60	100.00	571.0	

[a] Use differed from availability for:

Fain ($\chi^2 = 750.87$, $P < 0.001$);

Orme ($\chi^2 = 522.50$, $P < 0.001$);

Cherry ($\chi^2 = 700.49$, $P < 0.001$).

Table 2. Pronghorn use[a] of habitat rated by model within Game Management Unit 21, central Arizona, 1989-95.

Habitat quality	No. of locations	% of locations	Bonferroni 90% CI	km² available	% of area	No. of locations expected	Jacobs' *D*
High/no problems	0	0.00		0.00	0.00		
High/problems	228	8.83	7.50 - 10.16	22.90	1.60	41.4	0.96
Moderate	1,534	59.41	57.10 - 61.72	238.05	16.68	430.7	0.76
Low	618	23.93	21.92 - 25.94	350.46	24.56	634.1	
Poor	154	5.96	4.85 - 7.07	190.02	13.32	343.8	-0.42
Unsuitable	42	1.63	1.03 - 2.23	16.57	1.16	30.0	
Mapped unsuitable	6	0.23	0.00 - 0.46	609.11	42.68	1,102.0	-0.99
	2,582	99.99		1,427.11	100.00	2,582.0	

[a] Use differed from availability (x^2 = 1,907.52, $P < 0.001$).

(High+Moderate+Low) pronghorn habitat in GMU 21 by using our rating system. Ninety-two percent of the pronghorn locations occurred in sections rated in these quality classes.

Most overall habitat ratings occurred in GMU 21 (Table 2). Non-random (χ^2 = 1,907.52; df = 5; n = 2,582; $P < 0.001$) use of the rated sections by pronghorn occurred between 1989-92. Sections that were acceptable quality habitat (High+Moderate+Low) were the sections that pronghorn used at or above availability, whereas those sections we rated as being either Poor or Unsuitable were used less than available. We subjectively judged the performance of the rating system to be excellent in GMU 21.

GMU 2A. We began field evaluation in February 1995. The AGFD Wildlife Manager assisted us in obtaining written permission from land owners for access to private property, which took approximately 3 days. Permission was granted for 31 of the 35 identified land owners.

Team 1 completed field evaluation by early April 1995, over a period of 9 different days during February, March, and April. Inclement weather prevented us from consistently working in the GMU. Landowners denied access to a substantial number of the 1,445 sections we hoped to evaluate (Fig. 9).

Nearly all (98.5%) of the pronghorn locations occurred in surveyed sections that we rated as either High, Moderate, or Low quality. Thus, we effectively identified pronghorn habitat in GMU 2A using our rating system.

For the sub-area north of the AT&SF railroad line, we estimated that 263 km² of habitat were available to pronghorn. Of this habitat, we only evaluated 156 km² because access was denied for many sections. Virtually all of the habitat in this sub-area rated Moderate, offering few options for pronghorn to select from or avoid at the macro scale. The presence of I-40, scattered homes, and the fencing for the highway, railroad, and homes resulted in some the sections being rated in the Low quality rather than Moderate. Since over 40% of this sub-area was not evaluated and little substantial differences in quality occurred in the habitat, we could not detect (χ^2 = 1.06; df = 3; n = 385; P = 0.787) any selectivity by the 4 radio-collared pronghorn monitored there (Table 3). Thus, this sub-area provided little insight into the effectiveness of the rating system.

South of the AT&SF railroad line, we estimated that the 16 radio-collared pronghorn could freely move around within 2,049 km². We did not have permission to access 679 km² (33%) of the sub-area. A small portion of this sub-area was rated as High quality pronghorn habitat; nearly half of the sub-area was rated as Moderate (Fig. 9; Table 3). If the access-denied areas were removed from any analysis, 63% of the sub-area was rated as Moderate.

Pronghorn south of the railroad used (χ^2 = 458.73; df = 4; n = 1,350; $P < 0.001$) habitat out of proportion to availability. In general, pronghorn used sections rated as High or Moderate greater than availability, while using Low, Poor, or Unsuitable sections less than availability. Again, the *D*-values for the High quality classes were not greater than those for the Moderate, suggesting we could not discriminate better quality habitat or it was not as readily available to the radio-collared pronghorn as

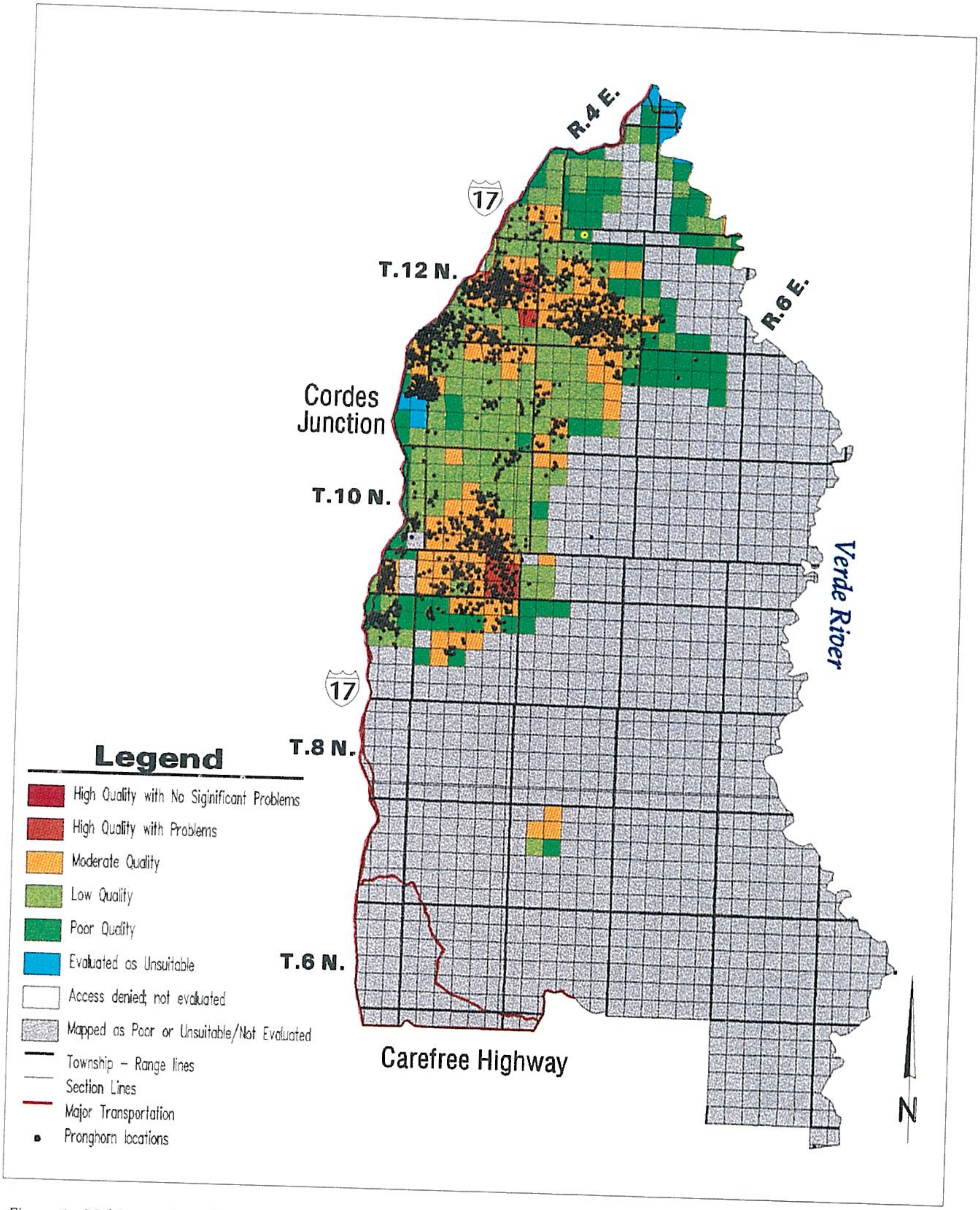


Figure 8. Habitat rating of Game Management Unit 21 overlaid with pronghorn locations, Arizona, 1989-95.

Table 3. Pronghorn use[a] of habitat rated by model within Game Management Unit 2A, northern Arizona, 1992-95.

North of AT&SF

Habitat quality	No. of locations	% of locations	km² available	% of area	No. of locations expected
High/no problems	0	0.00	0.00	0.00	
High/problems	0	0.00	0.00	0.00	
Moderate	167	43.38	113.51	43.23	166.4
Low	42	10.91	33.56	12.78	49.2
Poor	11	2.86	7.98	3.04	11.7
Unsuitable	0	0.00	1.16	0.44	1.7
Access denied	165	42.86	106.39	40.51	156.0
	385	100.01	262.60	100.00	385.0

South of AT&SF

Habitat quality	No. of locations	% of locations	Bonferroni 90% CI	km² available	% of area	No. of locations expected	Jacobs' *D*
High/no problems	0	0.00		10.32	0.50	6.8	-1.00
High/problems	81	6.00	4.42 - 7.58	34.23	1.67	22.6	0.58
Moderate	1,085	80.37	77.72 - 83.02	944.43	46.11	622.5	0.65
Low	94	6.96	5.26 - 8.66	379.02	18.51	249.9	-0.50
Poor	11	0.81	0.21 - 1.41	82.91	4.05	54.7	-0.67
Unsuitable	0	0.00		8.93	0.44	5.9	-1.00
Access denied	79	5.85	4.29 - 7.41	588.16	28.72	387.7	-0.73
	1,350	99.99		2,048.00	100.00	1350.1	

[a] Use versus availability for:

North of AT&SF ($\chi^2 = 1.06$, $P = 0.787$);

South of AT&SF ($\chi^2 = 458.73$, $P < 0.001$).

suspected. In support of the latter, the home ranges of many of our radio-equipped pronghorn simply did not include the areas of GMU 2A that were rated as higher quality.

Although the high percentage of non-evaluated habitat in GMU 2A confounded our analyses, we subjectively judged the rating system to be fair in the southern sub-area of GMU 2A. The major problem was in effectively identifying High quality habitat, areas that should have been significantly selected for by pronghorn but were not.

GMU 7E. Field maps were prepared for all of GMU 7 during August 1994. Our test area of GMU 7E was field evaluated by Team 2 between December 1994 and March 1995, over 22 days. Considerable habitat was above 2,100 m elevation and inclement weather slowed the field work.

We evaluated 602 sections (1,296 km²) in GMU 7E. Reasonably suitable habitat (High+Moderate+Low) occurred along the northern portion of the area, from Wupatki National Monument north, and along the eastern edge (Fig. 10). Very little of the GMU was rated as High (class 1-2) quality for pronghorn (Table 4). Much of the southern and western portions of GMU 7E was rated as lower quality (Poor or Unsuitable) for sustaining pronghorn.

In GMU 7E, Team 2 rated the habitat such that 95.6% of the pronghorn locations occurred in sections scored as either High, Moderate, or Low. For Team 1, 91.6% occurred in reasonable quality

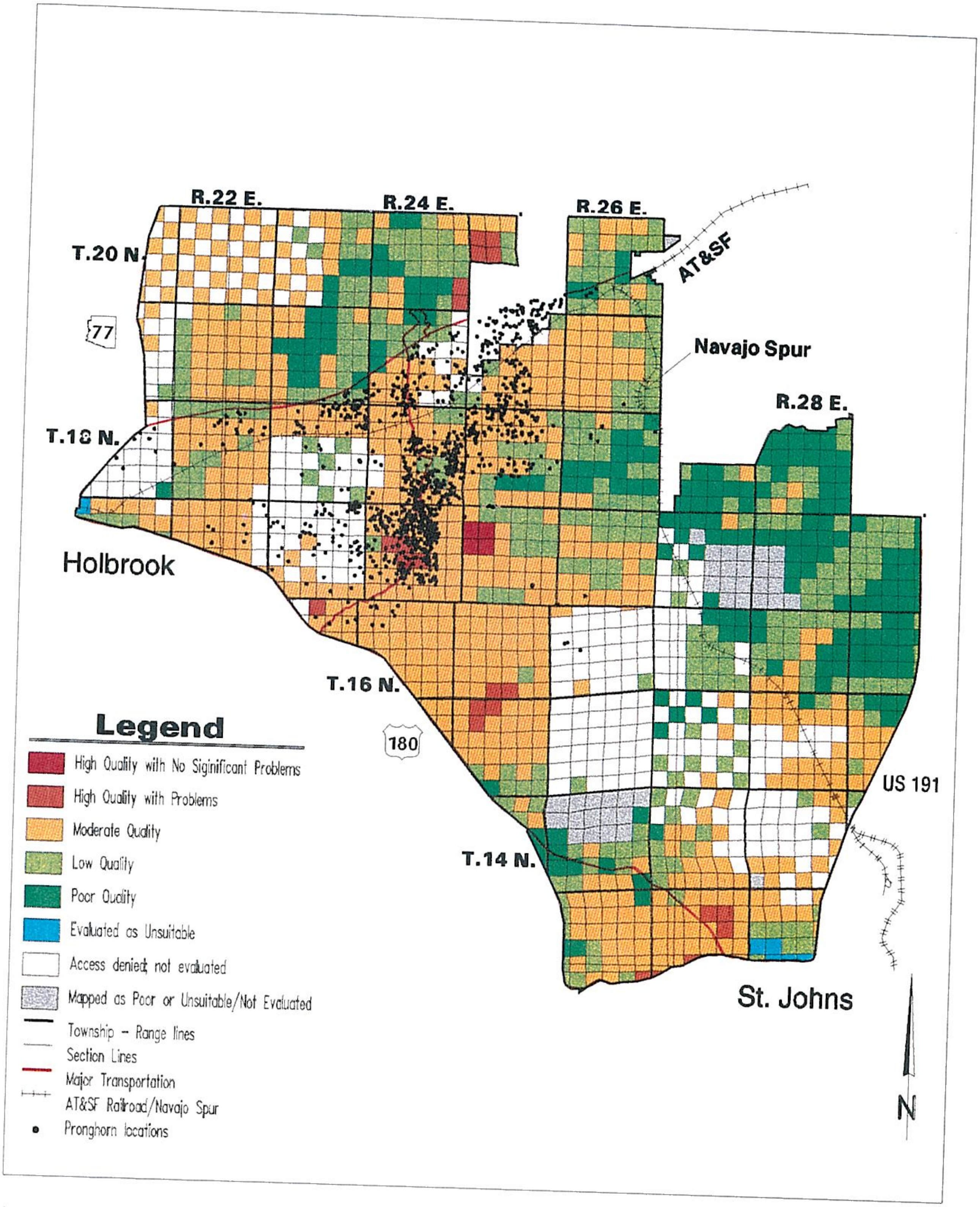


Figure 9. Habitat rating of Game Management Unit 2A overlaid with pronghorn locations, Arizona, 1992-95.

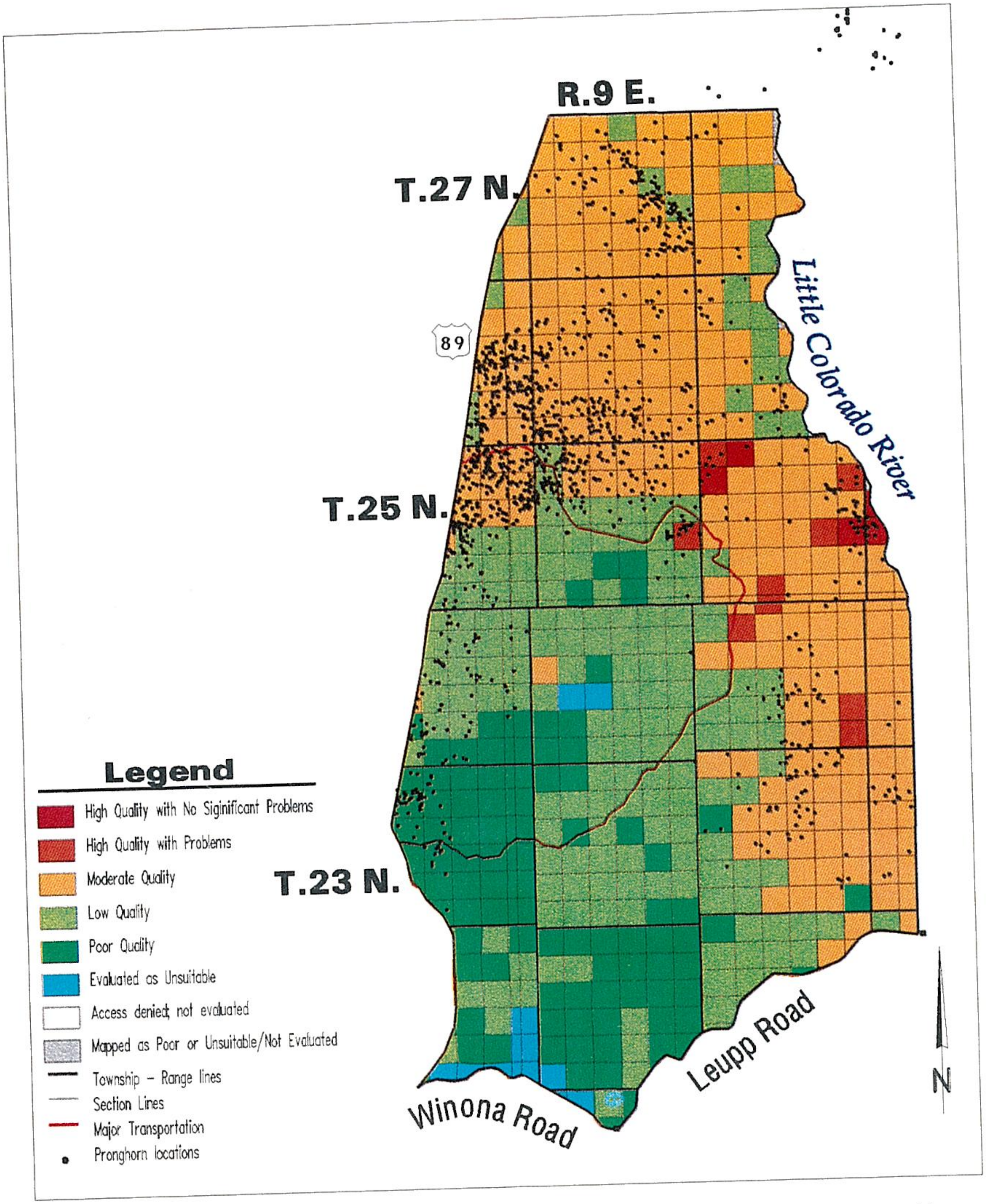


Figure 10. Habitat rating of Game Management Unit 7E overlaid with pronghorn locations, Arizona, 1992-95. This evaluation was completed with inexperienced personnel.

Table 4. Pronghorn use[a] of habitat rated by model within Game Management Unit 7E, northern Arizona, 1992-95. This evaluation was completed with inexperienced personnel.

Habitat quality	No. of locations	% of locations	Bonferroni 90% CI	km² available	% of area	No. of locations expected	Jacobs' *D*
High/no problems	23	1.38	0.70 - 2.06	10.26	0.79	13.2	
High/problems	22	1.32	0.65 - 1.99	21.62	1.67	27.9	
Moderate	1,197	71.63	68.99 - 74.27	579.69	44.72	747.3	
Low	355	21.24	18.85 - 23.63	436.37	33.66	562.5	0.51
Poor	74	4.43	3.23 - 5.63	228.84	17.65	294.9	-0.31
Unsuitable	0	0.00		19.57	1.51	25.2	-0.64
Mapped unsuitable	0	0.00		0.00	0.00	0.0	-1.00
	1,671	100.00		1,296.35	100.00	1,671.0	

[a] Use differed from availability (χ^2 = 304.80, P < 0.001).

habitat. Both teams identified pronghorn habitat with reasonable accuracy using our rating system.

The full range of habitat ratings occurred in GMU 7E. Non-random (χ^2 = 304.80; n = 1,671; P < 0.001) use of the sections by pronghorn occurred between 1992-94. The few surveyed sections initially rated by Team 2 as High (rated 1 or 2) were only used as available. Sections that were rated Moderate were used more than availability would predict, and those sections rated as being Low to Unsuitable for pronghorn were used less than available.

Overall, we subjectively judged the performance of the rating system with an inexperienced team to be fair. No selection was indicated for those sections rated the highest quality. However, these highly-rated sections were not avoided by pronghorn. Team 2, trained but inexperienced, had more problems identifying plant species that pronghorn would favor than did Team 1. Also, Team 2 had more difficulty in visually estimating percent cover of the different plant groups. Combined together, these problems substantially reduced their work speed. The number of sections rated decreased to <2.5 per hour, a 40-50% decrease in efficiency relative to the sections per hour from Team 1 in GMUs 19A and 21.

Subjectivity Tests

After Team 2 completed evaluating GMU 7E, Team 1 re-evaluated the area. This re-evaluation was completed during May 1995 (Fig. 11).

Team 1 had fewer sections rated in the 2 High classes than did Team 2 (Table 5). Jacobs' *D* results from Team 1 were similar to those of Team 2, as pronghorn selected and avoided (χ^2 =

Table 5. Pronghorn use[a] of habitat rated by experienced observers by model within Game Management Unit 7E, northern Arizona, 1992-95.

Habitat quality	No. of locations	% of locations	Bonferroni 90% CI	km² available	% of area	No. of locations expected	Jacobs' *D*
High/no problems	0	0.00		0.00	0.00		
High/problems	2	0.12	0.00 - 0.32	5.86	0.45	7.5	-0.58
Moderate	978	58.53	55.47 - 61.09	381.60	29.41	491.4	0.54
Low	551	32.97	30.29 - 35.65	430.35	33.16	554.1	
Poor	140	8.38	6.80 - 9.96	477.30	36.78	614.6	-0.73
Unsuitable	0	0.00		2.62	0.20	3.4	-1.00
Mapped unsuitable	0	0.00		0.00	0.00		
	1,671	100.00		1,297.73	100.00	1,671.0	

[a] Use differed from availability (χ^2 = 464.83, P < 0.001).

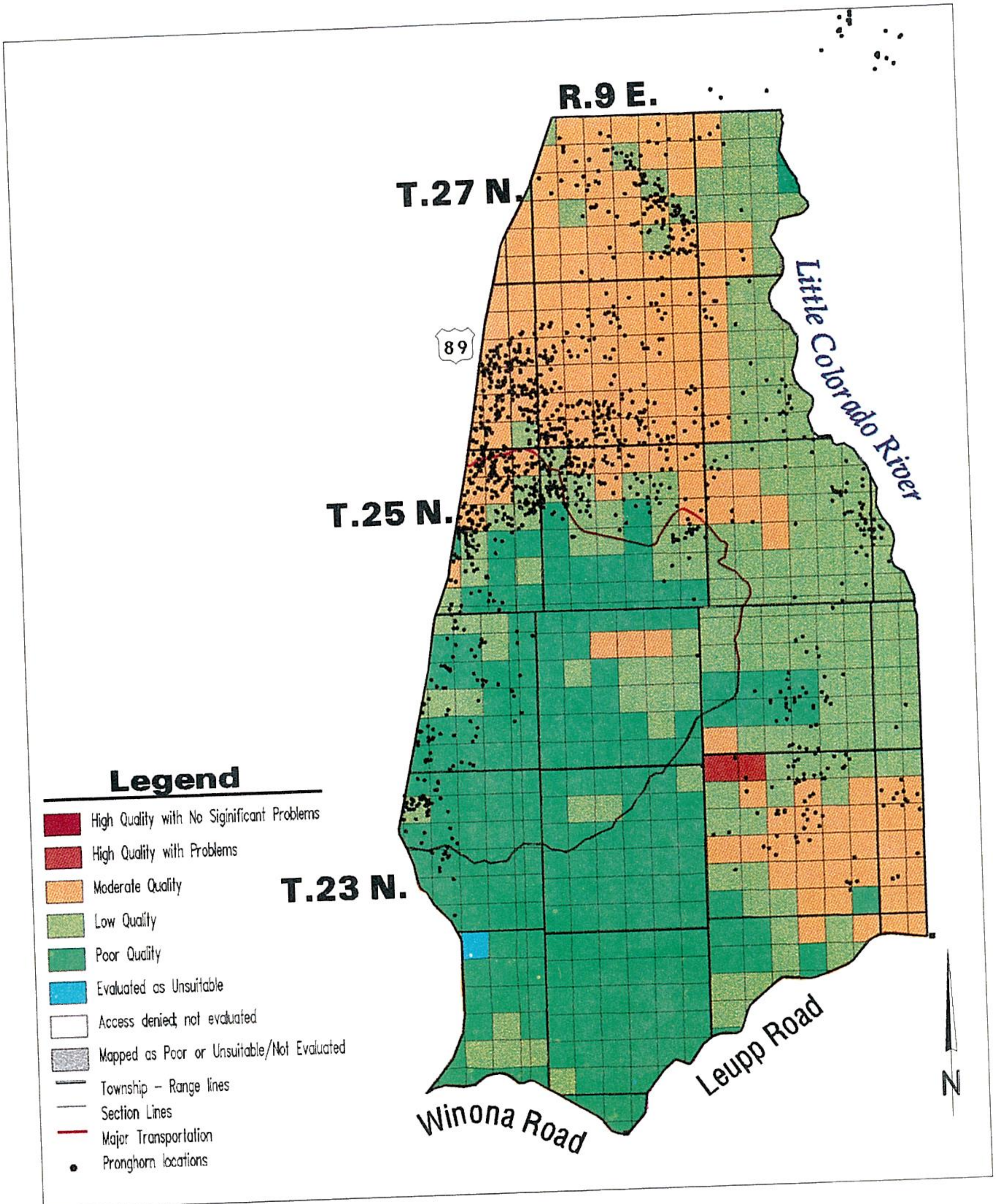


Figure 11. Habitat rating of Game Management Unit 7E overlaid with pronghorn locations, Arizona, 1992-95. This evaluation was completed with experienced personnel.

Table 6. Error matrix[a] between the initial overall habitat rating by inexperienced personnel (Team 2) and re-evaluation by experienced personnel (Team 1) for 553 sections in Game Management Unit 7E, northern Arizona, 1992-95.

	Team 2 rating					
Team 1 rating	High/ no problems	High/ problems	Moderate	Low	Poor	Unsuitable
High/no problems						
High/problems			2 (0.8)			
Moderate	1 (20.0)		139 (56.7)	17 (9.2)		
Low	4 (80.0)	9 (100.0)	99 (40.4)	67 (36.4)	5 (5.1)	2 (18.2)
Poor			5 (2.0)	100 (54.3)	93 (93.9)	9 (81.8)
Unsuitable					1 (0.1)	

[a] Number of sections (column percent).

464.83, df = 2, n = 1,671) habitats rather than used them as available. For sections rated as Moderate by Team 1, selection was indicated, sections rated Low were used as available, and those sections rated Poor or Unsuitable were avoided.

The most noticeable differences in Jacobs' D values between Team 1 and Team 2 were for those sections rated as High or Low quality. Team 1 rated considerably fewer sections High quality than did Team 2. Also, sections rated Low by Team 2 were avoided, but those rated Low by Team 1 were used as expected. Values for Moderate and Poor quality habitat were nearly identical. The patterns of selectivity from both teams seemed reasonable.

Examining data from individual surveyed sections in an error matrix between the 2 teams indicated that Team 1 tended to rate individual sections lower in quality than did Team 2 (Table 6). If Team 2 rated sections as High, Team 1 usually rated them 2 or 3 classes lower. This was primarily due to their differences in estimating tall shrub cover. For Moderate or Low quality, Team 1 tended to rate 1 class lower in quality; for Poor quality habitat, there was nearly total agreement between the 2 teams. Overall, agreement (concordance) between the 2 teams was poor (W = 0.241, n = 533).

Calculated differences between overall scores illustrated the disagreement between Team 1 and Team 2 (Fig. 12). The experienced team rated very few sections higher in quality than did the inexperienced team. Team 1, the experienced team, rated most (96.2%) sections 1 class less or the same than did Team 2.

We subjectively judged that it was apparent that ≤3 days of training in use of the rating system was inadequate to eliminate observer variability. The experience gained from years of locating and studying pronghorn was not compensated for by limited training.

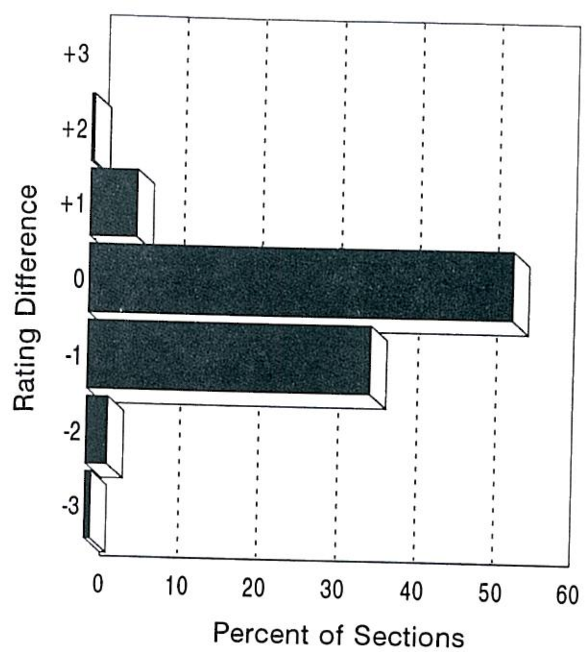


Figure 12. Difference in overall scores between the initial evaluation by inexperienced personnel (Team 2) and the re-evaluation by experienced personnel (Team 1) for 553 sections in Game Management Unit 7E, northern Arizona, 1995.

DISCUSSION

Using a minimum number of variables to evaluate pronghorn habitat seemed adequate for assessing a surveyed section of land at a landscape level. Ocular appraisals of the 5 categories were effective enough to identify suitable habitat. We also could separate relative levels of quality with reasonable consistency. However, our ability to discern higher quality habitat from more moderate was less than we hoped for. It is possible that what our model assumes is High quality habitat is not perceived as such by pronghorn. Certainly, pronghorn habitat requirements are not fully understood and additional studies are needed to increase our knowledge of their requirements. Pronghorn are known to be nomadic in their movements within acceptable habitat, reflecting short-term changes in forb production, water availability, disturbance levels, and weather conditions. Our rating system could not measure quality at that level.

Without an accurate assessment of forb production and water availability during the dry periods of the year, our model lacked the necessary variables to consistently distinguish minimal quality differences. Thus, a finer resolution assessment of reasonably suitable habitat, sections we classified as High, Moderate, and Low, seems necessary before management prescriptions are applied.

To use a rating system that was ground based and still complete a statewide assessment in a short time, we needed to minimize data collection and data entry time. Using a remote-sensing system would have been more cost effective and offset private property access problems. However, our limited attempts at using remote-sensing systems to distinguish habitat quality across Arizona had unsatisfactory results. Substantial ground verification and re-evaluation was necessary. By using just a few categories in a ground-based system, we hoped to optimize field personnel time; for this, we fell short of expectations.

Our model required personnel to visit virtually every surveyed section the potential map indicated as likely pronghorn habitat, although some areas could be viewed from vantage points. Sometimes we had to cover more area than that indicated on the potential map, and some areas only had primitive roads, which greatly increased travel time. Often, the time spent rating a section was considerably less than the time it took to get there.

Time efficiency and number of variables reduced the utility of our rating system. Improvements can be made by addressing problems associated with the following: (1) season of the year, (2) observer subjectivity, (3) the scale of the experimental unit (i.e., surveyed section), and (4) access to private property.

Season of the Year

The best scenario would be to assess pronghorn habitat twice a year, once during the spring greenup to estimate forb production and summer water availability, then again during the winter to assess their access to winter range and shrub availability. However, to evaluate habitat across the state in such a manner would be time and cost prohibitive. Therefore, we had to consider a different tack; one which would allow us to evaluate habitat independent of season.

To do so, we waived our ability to accurately assess forb production in a consistent manner across all GMUs. We needed an evaluation system that was equally proficient in assessing GMUs during the poor conditions of late summer and winter as well as assessing the better conditions of spring and early summer. Furthermore, yearlong evaluation precluded accurately assessing summer water availability, the most critical time in most of Arizona.

We estimated that the field effort necessary to evaluate all potential areas in Arizona would require about 5,000 hours. Using 2 experienced people working independently, this effort would require more than 2 years. If these 2 people worked only in the spring with a return in the winter to the same area, the statewide project could span 5-10 years.

The loss of finer resolution is a reasonable trade-off when assessing pronghorn habitat at a landscape level. Although, a later finer resolution assessment of suitable habitat should be conducted in specific areas as needed before management actions are taken.

Observer Subjectivity

Experienced and unexperienced observer teams did not have substantial agreement in the GMU where field results were compared. Without prior experience in studying pronghorn and with only limited training, the inexperienced team expressed difficulty in applying the rating system. The level of training we provided them, only 3 days, was deemed inadequate by them, and we agree. Several weeks of training would likely reduce subjectivity between individuals to an appropriate level.

We believe subjectivity was mainly caused by ocularly estimating percent cover of trees and shrubs for the vegetation category. Team 1 had >3 years of experience estimating canopy cover on 40-m^2 and 400-m^2 circular plots during the pronghorn location portion of the study. The inexperienced team had virtually no prior practice at such estimation.

Several options would minimize observer bias. First, use only 2 experienced observers. It would be easier to cross train and test between individuals if only 2 observers applied the model statewide. This option increases the time necessary to complete a statewide assessment than if numerous people worked on the project.

Another option would be to work in teams of 1 experienced person rating and 1 inexperienced observer driving, thus allowing experienced observers to rate more surveyed sections per hour than if they both drove and rated. Although the hourly rate of sections assessed would increase, using 2 people per vehicle would greatly increase costs.

Lastly, more training and testing could be provided for inexperienced observers. Logically, those with prior habitat assessment experience and experience with pronghorn habitat use and selection patterns should be better observers and require less training. We believe training should be conducted by the same experienced observers, who cross-check each other, to further reduce subjectivity.

Experimental Unit Scale

Although the use of TRS units ensured GIS compatibility of our model, assessing each surveyed section of land with an overall habitat quality rating created a dichotomy; it was too coarse a measure in areas with substantial heterogeneity, but too repetitive and time consuming in homogeneous landscapes.

An example of problems associated with the coarse resolution of the model, in township T13N, range R3E, was a small fawning area of the Cherry herd (20-25 animals) centered in the corners of 4 sections. Each of these sections was dominated by interior chaparral, which we scored as closed shrubland, a Poor quality vegetation class. Our overall scores for the 4 sections were Poor, yet radio-collared does used the small site as a fawning area. Similar situations exposing problems associated with the coarse resolution of the rating system occurred a few other times in the 4 GMUs where we evaluated it.

An example of problems associated with the repetitiveness of the model was evaluating the length of Lonesome Valley along the western edge of GMU 19A. This resulted in nearly 3 townships with each section rated Moderate with most individual categories scoring the same. Only minor differences occurred in most of the nearly 100 sections. A more efficient method of assessing large blocks of homogenous habitats would increase the efficiency of a statewide evaluation.

To standardize assessment across the entire state, the use of TRS was the best choice for a sample unit. It is quite possible that even with the use of the TRS system we would have in excess of 25,000 records in the final database. An obvious advantage of this system is that the records can be combined in a multitude of necessary covers for future analyses. In GIS, we could organize, map, display, and analyze the sections by BLM-managed lands, USFS lands, state lands, grazing allotments, or by counties, rather than just by the GMU.

Access To Private Property

Substantial amounts of habitat in Arizona suitable for pronghorn are privately owned, thus access must be granted by the landowner before an assessment can be completed. Although most private landowners cooperated with our research, several did not; this resulted in an incomplete assessment. We encountered difficulties in gaining access to substantial areas of GMU 2A; in the other GMUs, this was not the case. Private ranches in other GMUs in Arizona control substantial amounts of suitable land for pronghorn. Without written permission, a patchwork pattern of assessed habitat would occur, thereby limiting use in future planning efforts.

Substantial hours were expended to obtain signatures to authorize access before an assessment was conducted. This situation added considerably to costs by increasing the time and human resources necessary to complete the project. We have no reasonable estimate of what the impact of this constraint will have in terms of cost and time to a statewide effort, other than it will vary by GMU.

If access is finally granted, a later ground assessment could be done on these lands and easily added to the GIS database. Changes in landownership may reduce this concern over time, and the model could then be used to assess the area.

CONCLUSIONS

We believe our landscape-level model adequately accomplished our goal. Using this model on a statewide basis provides resource managers with a reasonable tool, a GIS database, to assist in long-term, landscape-level planning efforts. As with other assessment models, this model has strengths and weaknesses.

The strengths of this model are its:

- GIS compatibility
- Ability to be updated at any time for areas as small as a surveyed section
- Ability to be used independent of season
- Simplicity for experienced personnel to score an area
- Ability to produce a database that can be queried for numerous levels of planning

These strengths result in a reasonable product for assisting in land-use planning over large areas. The model was valid for numerous habitats, across many terrain possibilities, and for different levels of human-related disturbances. These characteristics are essential for statewide use.

The weaknesses of the model are its:

- Initial reliance on a vegetational mapping project that was coarse in resolution and was completed by numerous people
- Need to gain ground access on private property
- Scale of measurement (surveyed section as the unit area evaluated by TRS)
- Substantial observer subjectivity

Satellite imagery may have provided finer resolution for mapping potential areas than did the Arizona Game and Fish Department's vegetational mapping project. However, obtaining statewide coverage was cost prohibitive.

Observer subjectivity can be adequately controlled. Using a minimum number of well-trained observers, who use double-sampling techniques and continually cross-train each other, should reduce this bias to an acceptable level.

The other weaknesses of the model do not seem to be fatal flaws, nonetheless, each reduces the effectiveness of the final product.

We believe 3 major products could be developed from a statewide evaluation of habitat suitability for pronghorn if this model is used: (1) a special report describing the evaluation of each GMU, complete with a detailed map; (2) a database file of each GMU or appropriate political subdivision that allows resource managers easy access and updating capabilities; and (3) a GIS database, developed for ArcView®, that allows resource managers to spatially evaluate impacts and plan projects within pronghorn habitat.

With the rapid growth of the human population in Arizona (Walker and Bufkin 1986) and the historical degradation of grassland and woodland habitats (Griffiths 1901, Hastings and Turner 1965, Bahre 1991), the need for a statewide appraisal of the suitability of habitat for supporting pronghorn seems critical. Our model is a sufficient tool to assist in such an assessment. A more detailed future assessment of habitat quality needs to be conducted in some areas, based on management needs and possible prescriptions to improve habitat quality.

Lastly, research is warranted on determining which existing habitat evaluation model is most appropriate for finer resolution assessments in Arizona. Such an assessment would further aid resource managers in determining translocation priorities and designing habitat improvement projects.

LITERATURE CITED
(Includes Appendix A)

Allen, A. W., and M. J. Armbruster. 1982. Preliminary evaluation of a habitat suitability model for the pronghorn. Proc. Pronghorn Antelope Workshop 10:93-105.

___, J. G. Cook, and M. J. Armbruster. 1984. Habitat suitability index models: pronghorn. U.S. Fish and Wildl. Serv. Office Biol. Serv. Rep. 82/10.65, Washington, D.C. 22pp.

Anderson, S. H., and K. J. Gutzwiller. 1994. Habitat evaluation methods. Pages 592-606 *in* T. A. Bookhout, ed. Research and management techniques for wildlife and habitats. Fifth Ed. The Wildl. Soc., Bethesda, Md. 704pp.

Arizona Game and Fish Dep. 1993. Game management program: appendix 8, guide to prioritizing pronghorn antelope transplant sites. Ariz. Game and Fish Dep. Strateg. Plans and Manage. Guidelines, Phoenix. Unnumbered pages.

Autenrieth, R., editor. 1978. Guidelines for the management of pronghorn antelope. Proc. Pronghorn Antelope Workshop 8:473-526 (1983 reprint of original 1978 publication by Texas Parks and Wildl. Dep., Austin).

Bahre, C. J. 1991. A legacy of change: historic human impact on vegetation in the Arizona borderlands. Univ. Arizona Press, Tucson. 231pp.

Beasom, S. L., E. P. Wiggers, and J. R. Giardino. 1983. A technique for assessing land surface ruggedness. J. Wildl. Manage. 47:1163-1166.

Brown, D. E., editor. 1994. Biotic communities: southwestern United States and northwestern Mexico. Univ. Utah Press, Salt Lake City. 342pp.

___, and C. H. Lowe. 1974. A digitized computer-compatible classification for natural and potential vegetation in the Southwest with particular reference to Arizona. J. Ariz. Acad. Sci. Vol. 9, Suppl. 2. 11pp.

Buechner, H. K. 1950. Life history, ecology, and range use of the pronghorn antelope in Trans-Pecos Texas. Am. Midl. Nat. 43:257-355.

Byers, C. R., R. K. Steinhorst, and P. R. Krausman. 1984. Clarification of a technique for analysis of utilization-availability data. J. Wildl. Manage. 48:1050-1053.

Carrel, W. 1972*a*. Forward phased twin-yagi antenna array. Inter. Assoc. Natur. Resourc. Pilots Handbook, unpubl. mimeo.

___. 1972*b*. Removable rotary antenna handle for aerial radiotracking. Inter. Assoc. Natur. Resourc. Pilots Handbook, unpubl. mimeo.

Cook, J. G., and L. I. Irwin. 1985. Validation and modification of a habitat suitability model for pronghorns. Wildl. Soc. Bull. 13:440-448.

___, ___, A. W. Allen, and M. J. Armbruster. 1984. Field test of a winter pronghorn habitat suitability index model. Proc. Pronghorn Antelope Workshop 11:207-223.

Firchow, K. M., M. R. Vaughan, and W. R. Mytton. 1986. Evaluation of the hand-held net gun for capturing pronghorns. J. Wildl. Manage. 50:320-322.

Griffiths, D. A. 1901. Range improvement in Arizona. U.S. Bur. Plant Indust. Bull. 4, Washington, D.C. 31pp.

Hailey, T. L. 1979. A handbook for pronghorn antelope management in Texas. Texas Parks and Wildl. Dep. Fed. Aid Rep. Ser. 20, Austin. 59pp.

Hastings, J. R., and R. M. Turner. 1965. The changing mile: an ecological study of vegetation change with time in the lower mile of an arid and semiarid region. Univ. Arizona Press, Tucson. 317pp.

Hoover, R. L., C. E. Till, and S. Ogilvie. 1959. The antelope in Colorado. Colo. Dep. Game and Fish, Denver. 110pp.

Howard, V. W., Jr., J. L. Holechek, R. D. Pieper, S. L. Beasom, and K. Green-Hammond. 1983. Roswell pronghorn study. New Mexico State Univ. Contract Rep. VA-512-RFP9-10, Las Cruces. 115pp.

____, ____, ____, K. Green-Hammond, M. Cardenas, and S. L. Beasom. 1990. Habitat requirements for pronghorn on rangelands impacted by livestock and net wire in eastcentral New Mexico. New Mexico State Univ. Agric. Exp. Stn. Bull. 750, Las Cruces. 48pp.

Irwin, L. I., and J. G. Cook. 1985. Determining appropriate variables for a habitat suitability model for pronghorns. Wildl. Soc. Bull. 13:434-440.

Jacobs, J. 1974. Quantitative measurements of food selection. Oecologia 14:413-417.

Kearney, T. H., and R. H. Peebles. 1960. Arizona flora. Univ. California Press, Berkeley. 1,085pp.

Kindschy, R., C. Sundstrom, and J. Yoakum. 1978. Range/wildlife interrelationships--pronghorn antelope. Proc. Pronghorn Antelope Workshop 8:216-269.

____, ____, and ____. 1982. Wildlife habitats in managed rangelands--the Great Basin of southeastern Oregon: pronghorns. U.S. For. Serv. Gen. Tech. Rep. PNW-145. 18pp.

Knipe, T. 1944. The status of the antelope herds of northern Arizona. Ariz. Game and Fish Comm. Fed. Aid Proj. Rep., Phoenix. 40pp.

Lehr, J. H. 1978. A catalogue of the flora of Arizona. Ariz. Desert Botan. Garden, Phoenix, and Northland Press, Flagstaff. 203pp.

McCarthy, C., and J. Yoakum. 1984. An interagency approach to evaluating pronghorn transplant sites in Mono County, California. Proc. Pronghorn Antelope Workshop 11:134-143.

Neff, D. J. 1986. Pronghorn habitat description and evaluation: a problem analysis report. Ariz. Game and Fish Dep. Fed. Aid Wildl. Restor. Proj. W-78-R Final Rep., Phoenix. 15pp.

Nelson, E. W. 1925. Status of the pronghorn antelope: 1922-1924. U.S. Dep. Agric. Bull. 1346, Washington, D.C. 64pp.

Neu, C. W., C. R. Byers, and J. M. Peek. 1974. A technique for analysis of utilization-availability data. J. Wildl. Manage. 38:541-545.

Ockenfels, R. A. 1994. Mountain lion predation on pronghorn in central Arizona. Southwest. Nat. 39:305-306.

____. In prep. Evidence of historical pronghorn distribution in Arizona. Ariz. Game and Fish Dep., Phoenix.

____, A. Alexander, C. L. Dorothy Ticer, and W. K. Carrel. 1994. Home ranges, movement patterns, and habitat selection of pronghorn in central Arizona. Ariz. Game and Fish Dep. Tech. Rep. 13, Phoenix. 80pp.

O'Gara, B. W., and J. D. Yoakum, editors. 1992. Pronghorn management guides. Proc. Pronghorn Antelope Workshop 15 (Suppl.). 101pp.

Sundstrom, C., W. G. Hepworth, and K. L. Diem. 1973. Abundance, distribution, and food habits of the pronghorn. Wy. Game and Fish Comm. Bull 12, Cheyenne. 61pp.

Thomas, D. L., and E. J. Taylor. 1990. Study designs and tests for comparing resource use and availability. J. Wildl. Manage. 54:322-330.

U.S. Dep. Agric. 1989. Wildlife habitat evaluation guides for antelope in Arizona. U.S. Soil Cons. Serv. Unpub. mimeo., Phoenix. 2pp.

Van Horne, B. 1983. Density as a misleading indicator of habitat quality. J. Wildl. Manage. 47:893-901.

Walker, H. P., and D. Bufkin. 1986. Historical atlas of Arizona. Second ed. Univ. Oklahoma Press, Norman. 65pp.

Yoakum, J. D. 1974. Pronghorn habitat requirements for sagebrush-grasslands. Proc. Pronghorn Antelope Workshop 6:16-24.

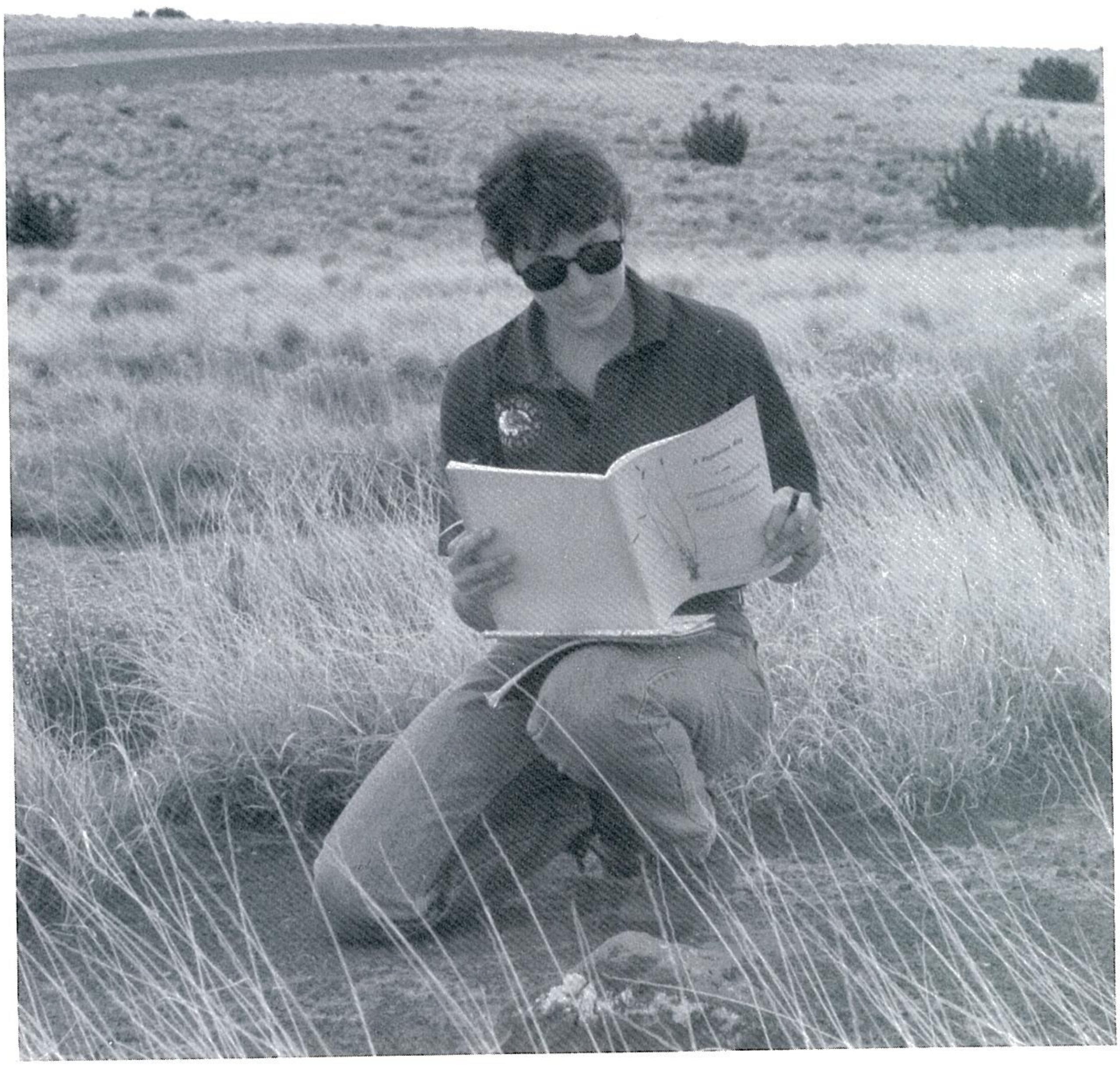
____. 1978. Pronghorn. Pages 103-121 *in* J. L. Schmidt and D. L. Gilbert, eds. Big game of North America: ecology and management. Wildl. Manage. Inst., Washington, D. C., and Stackpole Books, Harrisburg, Pa. 494pp.

___. 1979. Managing rangelands for pronghorns. Rangelands 1:146-148.

___. 1980. Habitat management guides for the American pronghorn antelope. U.S. Bur. Land Manage. Tech. Note 347, Denver, Colo. 78pp.

___. 1990. Food habits of the pronghorn. Proc. Pronghorn Antelope Workshop 14:102-111.

Zar, J. H. 1984. Biostatistical analysis. Second ed. Prentice-Hall, Englewood Cliffs, N.J. 718pp.



Biologist identifying grass and shrub species while evaluating pronghorn habitat.

APPENDIX A. Evaluation of Previous Pronghorn Habitat Models

Colorado Translocation Feasibility Guides

For this early attempt at pronghorn habitat assessment, Hoover et al. (1959) developed a set of guidelines to evaluate proposed sites for reintroduction of pronghorn in Colorado. Yoakum (1980) modified those guidelines for use in sagebrush grasslands. O'Gara and Yoakum (1992) considered 8 of the criteria important enough to modify for continued use. The 8 criteria were:

- Sufficient continuous rangeland available, being at least 1 km^2 per animal and the minimum number of animals at 100
- Presence of a good variety of forage forbs and shrubs
- Rangeland ecological condition and the density of tall shrubs
- Competition with domestic livestock, including diet overlap
- Fencing structure and density
- Predator control practices
- Potential for depredation to agricultural crops
- Landownership patterns

Each guideline only helped resource managers identify whether or not a site was suitable or unsuitable for future translocation efforts. Since our goal was to provide resource managers a tool that not only identified suitable habitat but rated its relative quality, these guidelines were inadequate for use in Arizona.

Predator control practices, depredation to agricultural crops, and landownership patterns are not factors that directly reflect the innate suitability of an area to support pronghorn. Rather, these factors indicate the management of the population. These factors were not appropriate in meeting our goal of assessing habitat suitability.

However, the guidelines provided a basis for future habitat assessment systems. We believed that assessing such variables as species composition, vegetational height, and fencing density and structure would assist us in meeting our goal. Although the size of an area was an inappropriate variable for us, being set by us at a surveyed section to accommodate GIS needs, this variable could be used later in applications of the database.

Great Basin Function Curves

Kindschy et al. (1978) presented a series of function curves that described the relationship between pronghorn density (number per km^2) and habitat characteristics in Great Basin sagebrush steppe. Their premise was that pronghorn density was controlled by characteristics of the habitat. Four graphs representing habitat characteristics were presented:

- Distance to water, with the optimum pronghorn density area of the curve ranging from 0-1.6 km
- Percent ground cover by shrubs, with the optimum range between 5-20%
- Percent ground cover by forbs, with the optimum range between 10-30%
- Vegetational height, with the optimum range between 25-46 cm

The area of overlap of these 4 factors was used to define optimum habitat for pronghorn. Optimum habitat was able to support at least 7.8 pronghorn per km^2. Supportive information dealt with the physiography of the land, natural barriers, precipitation, vegetational species composition (particularly species richness), the presence of other ungulates, and the presence of predators.

Based on all the aforementioned information, 4 classes of pronghorn productivity were identified: (1) class I, sites with the most potential for productivity; (2) class 2, intermediate productivity; (3) class 3, marginal productivity; and (4) class 4, no potential for pronghorn productivity.

Although this rating system was developed specifically for sagebrush steppe habitat, the variables measured/estimated seem appropriate for other habitats. However, inclusion of forb cover in the model severely limited year-round field application. Furthermore, because of the intensity of data collection, this model would have better application in relatively small areas (i.e., $<1,000$ km^2). Use over large areas such as counties or states seemed impractical.

Modifications would be necessary to use this model over the full range of pronghorn habitat in Arizona. Evaluating forb cover for a landscape-level project would be both too time specific and too labor intensive. The other variables could be assessed year round, although water availability would best be appraised during dry seasons or drought conditions.

A key premise for this model was that vegetational characteristics and terrain at evaluation sites must allow excellent visibility for pronghorn to detect and escape predators, while still providing adequate forage. This point we considered extremely important for all habitats and incorporated it into our rating system.

Bureau of Land Management Suitability Criteria

Yoakum (1980) provided a suitability survey form for translocation sites in sagebrush grasslands, modified from Hoover et al. (1959). Furthermore, he suggested that an inventory be done of an area and results compared to pronghorn habitat requirements. To do so, inventory data would be collected, summarized, and compared to suitability criteria. Three quality classes of suitability were noted: (1) good, (2) fair, and (3) poor. Points would be awarded for each quality class. A range of scores within a suitability class was used for several factors. For example, water availability for the good quality class ranged from 10-20 points in the overall score.

The following factors were scored into 1 of the quality classes:

- Water availability
- Percent ground cover of forbs
- Percent ground cover of grasses
- Percent ground cover of shrubs
- Size of the area
- Average vegetational height

The suitability of the site was reflected by the summation of scores. The overall range of scores was 5-105.

This rating system was designed to assess suitability in a specific habitat type, sagebrush grassland, that was already identified as pronghorn habitat. This was too narrow in scope and inappropriate for us because we needed to both identify and rate the relative quality of habitat.

Conceptually, it would provide us a framework for finer resolution evaluation in appropriate areas in the future. However, several important factors influencing habitat quality were not assessed by this method. There was no means of assessing human development or disturbance, nor was fencing density and structure adequately addressed. Significantly, topography was not addressed, a major factor determining habitat quality for pronghorn. These factors had to be accounted for in our modeling efforts.

U.S..Forest Service Great Basin Work Sheet

This rating system, an improvement on the Great Basin Function Curve model, was developed by Kindschy et al. (1982) to evaluate Great Basin sagebrush steppe habitat. The system used a numeric rating of 7 variables summed to relate to the overall quality of an area. The 7 variables were:

- Availability (distance between sources) of waters; 6 classes
- Percent shrub cover; 6 classes
- Percent forb cover; 6 classes
- Average vegetational height; 6 classes
- Duration of vegetational succulence; 5 classes
- Fence structure; 5 classes
- Average percent slope of the area; 4 classes

Each class was a percent of the optimum value, ranging from 0 to 100. The variable scores were then summed and divided by the number of categories rated. For summer range, all 7 categories were used. However, for winter range only 5 were used; water availability and vegetational succulence were not rated. The lowest value of the variables rated was assumed to be the primary limiting factor for the evaluated area.

Most of the variables are easy to evaluate, but realistic estimates of vegetational succulence duration would require serial measurements. In the arid Southwest, this value could vary substantially by year and localized area.

All variables contributed equal weight to the overall score; we considered this inappropriate for application to southwestern pronghorn habitat. Terrain, estimated by average slope, accounted for only 14.2% (1 of 7 categories) of the overall score, which was the same relative contribution to the score as fences. Vegetational factors accounted for 57.1% (4 of 7 categories). Additionally, there was no assessment of the percent cover of trees, what was an important omission for our application in Arizona.

In general, this model was designed to rate area-specific habitat that had already been identified as suitable for pronghorn. We needed a system to determine unsuitable habitat as well as degrees of suitability for habitat that could be used by pronghorn. Thus, we found that this work sheet was not acceptable for assessing the quality of habitat for pronghorn on a statewide landscape basis.

Conceptually, this rating system was simple to use, it identified and addressed most important variables, and could easily be modified for the GIS. We incorporated most of their variables into our rating system.

Arizona Game and Fish Department Transplant Guides

In the early 1980s, the Arizona Game and Fish Department developed a set of evaluation criteria to score candidate areas for possible pronghorn reintroduction. These criteria have since been used as reintroduction guidelines and are included in the strategic planning Game Management Program document (Ariz. Game Fish Dep. 1993).

Based on a ranking between 1 (the lowest rating) and 4 (highest rating) for each criteria, use of the guides results in an aggregate score for each site being evaluated. Prioritization of sites was then determined by comparing overall scores. For typical application, 3 evaluators assess each site for all factors and their average score was the final composite rating (R. Lee, Ariz. Game and Fish Dep., pers. commun.).

Twelve criteria were evaluated at each site, all with equal weight in the cumulative score. They were:

- Historic occurrence of pronghorn
- Land status
- Topography
- Cover
- Range condition
- Presence of other ungulates
- Fences
- Seasonal availability of habitat
- Available water
- Habitat discreteness
- Human disturbance
- Range expansion potential

If a rating of 1 was encountered for any category, the guides precluded the site as a suitable transplant area. If a high enough score resulted from the assessment, then the resource manager initiated the necessary policy steps for a pronghorn transplant.

We believe the shortcomings of this method are as follows. First, based on our literature review and field experience, all 12 variables should not contribute the same weight in an overall score. Certainly, landownership should not be a factor in habitat quality, rather, it may be a factor in why the habitat was in its present condition, its stability against change, or whether resource managers could even modify its condition. Landownership could change and the rating would change, even though the present on-the-ground quality would not change. We considered documenting historical pronghorn range as too subjective, and we believed it to be less important than either topography, vegetative cover, or existing rangeland condition in identifying suitable habitat.

Second, the criteria for each category was subjective. Because of this, lack of consistency would likely be a problem over a long-term project involving many people. For example, the topographic category had no percent slope reference values to ascertain whether the surface was level, low rolling hills, low hills, folds, swales, or some other commonly-used descriptions of the ruggedness of an area. It was not possible to determine historic density, and anecdotal accounts of sizable numbers was not an acceptable representation of how many animals may have been present.

Third, some of the categories overlapped in terms of the factors being evaluated. For example, cover, rangeland condition, and the presence of other ungulates assessed similar variables; also, topography and habitat discreteness somewhat did the same thing.

The guides could be modified for statewide usage. Particular categories could be subjectively weighted to more heavily impact the overall score relative to other categories. These guides could be compatible with a GIS with minimal changes, and reference values could be added to the criteria to reduce subjectivity and increase rater consistency. Also, we could reduce redundancy by using fewer categories.

Overall, we believe topography, cover, and rangeland condition categories to be the most important of those used in this model. Of somewhat lesser importance, but still having an impact on the suitability of habitat, were presence of other ungulates, fences, available water, and human disturbance. We considered the historic occurrence of pronghorn, land status, seasonal availability, and habitat discreteness to be important attributes, but not directly relevant to a surveyed section's innate suitability to support pronghorn.

New Mexico State Viability Index

This model was developed by NMSU to assess sheep pastures in the Roswell area for their ability to support pronghorn (Howard et al. 1983). This model used the number of breeding pronghorn females as its index of suitability; thus, for a pasture to be suitable, it had to provide resources necessary to support or increase the current number of breeding females. The viability index of a pasture was calculated as the ratio of current breeding females after a period of time to the number of initially stocked breeding females. The viability index was then regressed against a set of independent variables for 18 study pastures. The best regression results had 4 variables that explained 75.7% of the variation in the viability index. These 4 variables were:

- A ruggedness index
- Pasture size in sections
- Average number of forb species in the fall
- Average number of sheep stocked in the fall, in animal units per 2.59 km^2

The ruggedness index, a measure of topographic relief within the pasture, was negatively correlated (r = -0.58) to the viability index. That is, the more rugged a pasture was, the less suitable it was for maintaining a pronghorn population over time. Terrain ruggedness has long been considered a major factor influencing the distribution of pronghorn (Yoakum 1974, O'Gara and Yoakum 1992). The ruggedness index was calculated following procedures outlined by Beasom et al. (1983). Howard et al. (1990) recommended a ruggedness index of $\leq$75 (e.g., less than high rolling hills) before pastures be considered suitable pronghorn range.

Pasture size was negatively correlated with viability and was of concern to Howard et al. (1983) because it reflected covariance of pasture size and ruggedness in their study area. The larger the pasture, the more likely it would have more rugged terrain. They concluded that pasture size should override the terrain factor in determining the suitability of pastures for stocking pronghorn. After re-evaluating the study, Howard et al. (1990) recommended a minimum pasture size of 13 km^2 for stocking of pronghorn.

The number of forb species present within the pasture, taken during a fall survey, was positively correlated to the pasture's viability to maintain breeding females; forbs are the preferred forage for pronghorn (Howard et al. 1990, Yoakum 1990). Unfortunately, this time-specific variable restricts when a field assessment could occur, and it would be a time-consuming task to conduct adequate surveys over large areas.

Because this model was developed to be time-specific and designed for evaluating sheep pastures, it was clearly inappropriate to us for assessing habitat quality in Arizona on a statewide basis. However, the concepts for the variables were appropriate. They related to the basic habitat requirements of pronghorn and needed to be considered in the development of a landscape-level model. Pasture size could easily be combined with fencing structure in a model, however, evaluating forbs year round would be nearly impossible.

Habitat Suitability Index Model

Allen et al. (1984) developed a habitat suitability index (HSI) model specifically for the Great Basin area, but extended it into the Great Plains. They clearly noted that the model was inappropriate for most of Arizona because the model assumptions were driven by the high likelihood of severe winter weather negatively affecting adult survival and reproductive success; the model was deemed appropriate for Great

Basin-like habitats in Arizona north of the Colorado River.

Cook et al. (1984) and Cook and Irwin (1985) field tested the Allen and Armbuster (1982) preliminary version of the winter HSI model. They were able to improve the model's performance to explain 70% of the variation in wintering pronghorn densities. The HSI model (Allen et al. 1984) included modifications due to this field test. Although the resultant level of performance seemed adequate, the fact that the model only assessed winter habitat in more northern states severely limited its applicability in Arizona.

Additionally, Irwin and Cook (1985) tested the winter model's variables against population parameters from 29 wintering herds to further validate model variables. To do so required measuring numerous variables, such as canopy cover of >6 vegetational categories and shrub height of many species. The field effort was more time-consuming than we desired for a statewide assessment. They concluded that shrub canopy cover and topographic diversity, the model's 2 most important variables, were appropriate to use, but shrub height was only weakly supported by their data. However, shrub height is considered an important factor in many other areas.

Because of the model's limited scope (winter only), the intensive data collection requirement, and the fact that it was developed primarily for evaluating areas <300 km², we concluded that this model was inappropriate for use in Arizona. To generalize this model for our use, we included 3 variables from this model: (1) rough measures of canopy cover, (2) topography, and (3) vegetational height.

Elements of the HSI model we found most useful were: (1) optimum shrub crown cover was 15-30%, (2) optimum height of the canopy was 18-46 cm, and (3) optimum number of shrub species present per cover type was ≥4. The model used topographic diversity to accommodate snow depth as a limiting factor. This variable is not important for most of Arizona under typical climatic conditions. But in rare circumstances where pronghorn migrations are obstructed by natural or human-related barriers, this could be the most important issue for pronghorn survival.

California Translocation Criteria

McCarthy and Yoakum (1984) developed an interagency plan for 9 biologists to assess 5 possible pronghorn reintroduction sites in California. The system was based on habitat suitability criteria developed by Yoakum (1980) for sagebrush grasslands. Four of the sites were Great Basin sagebrush grasslands, whereas the other site was predominately high desert shrub habitat.

Nine criteria were used in each assessment. One of them, habitat quality, included 4 of the habitat factors noted by Yoakum (1980). The 9 criteria were:

- Habitat quality, including
  -Water distribution
  -Forage quality
  -Forage quantity
  -Vegetational height
- Snow depth
- Natural barriers
- Size of area
- Passableness of fences
- Potential for predation (i.e., high, moderate, or low)
- Potential for depredation (i.e., high, moderate, or low)
- Seasonal suitability (i.e., year round or not)
- Competition with herbivores (i.e., high, moderate, or low)

Habitat quality was a numerical rating, a compilation score of the 4 factors, ranging from 0-100. This was done for each habitat type within the translocation site, then averaged for the entire site. Snow depth only asked if the habitat was suitable or unsuitable, with a threshold of >25 cm of snow in an area being deemed unsuitable for winter use. Fences were judged passable if the bottom strands were >41 cm above ground. The team also measured the kilometers of fences per km² at each site to assist in their assessment.

As with several of the previous rating systems we reviewed, this method was developed to assess specific sites for translocation of pronghorn. Data collection using this method would be too labor intensive for our application in Arizona.

Conceptually, this rating system incorporated most of the factors that we believed would provide us a reasonable tool to identify and evaluate relative quality of any habitat to support pronghorn. These we incorporated into our rating system.

Soil Conservation Service Rating

The U.S. Soil Conservation Service (SCS) developed an unpublished evaluation guide to assess habitat quality of an area relative to pronghorn. This 1989 system used 9 categories that were weighted from 1-4. The factors, with their weighting value, were:

- Plant communities (1)
- Landscape (1)
- Cover (2)
- Rangeland condition (3)
- Total annual utilization of forbs and shrubs (3)
- Grazing management (2)
- Vegetative composition (4)
- Water availability (2)
- Fencing (2)

The overall score was the sum for all categories divided by 20. Each category had 3 classes to chose from, with a narrow range of values for each class. For example, rangeland condition classes were poor (0-0.3), fair (0.8-1.0), or excellent to good (0.4-0.7). We assumed that these rangeland condition descriptors followed the standard range management system of determining whether rangeland was in poor, fair, good, or excellent condition. No documentation accompanied the model. For example, no explanation was given as to why habitat in fair rangeland condition would score higher than rangeland in good to excellent condition. The resultant score for rangeland condition was multiplied by its weighting factor of 3, then added to the other scores.

Some of the variables were insufficiently defined, however, minor modifications could correct this shortcoming. This modelling approach included other more serious shortcomings. For example, the plant community category did not include such suitable vegetation types as open conifer forest or unsuitable types, such as chaparral or closed conifer forests, nor did it differentiate between open or closed pinyon-juniper (P-J) woodlands. All P-J woodlands received a score between 0-0.3, which was too narrow a range for our application and was contrary to results from our habitat selection study (Ockenfels et al. 1994).

Nevertheless, all of these shortcomings could be corrected. With the deletion of the utilization category, which would require intensive field measurements to adequately document it, the model could be modified to be compatible to a GIS, detailed reference values could be added, and weighting factors could be adjusted to correspond with reviewed literature.

Overall, most variables in this model were conceptually adequate to be used for a statewide assessment. But not all variables were appropriate for our purpose. Livestock grazing strategies and percent use of forbs and shrubs change over short periods of time, and these factors, although likely important, would be difficult to evaluate statewide. For example, year-round rangeland that was lightly grazed would receive a score of 0-0.3, a narrow range. Certainly in some cases, a lightly-grazed rangeland, grazed year round, should score better than a heavily-grazed, rest-rotation system, which would be scored in the range of 0.4-1.0. This on-the-ground situation could not be accounted for with the SCS system. Further, evaluating percent use would require repeated measures, a feature not compatible with a statewide, year-round assessment. Nevertheless, percent use influences the suitability of habitat to support pronghorn.

Some variables were redundant in the SCS system. Cover categories for fawning cover and rangeland condition, percent use of forbs and shrubs, and vegetational composition were interrelated. With such redundancy, terrain could only account for 11.1% of the overall score, which in our opinion, was low.

APPENDIX B. A Landscape-level Pronghorn Habitat Evaluation Model for Arizona

This landscape-level evaluation system is based on the Township-Range-Section (TRS) database in the Arizona Game and Fish Department (AGFD) Geographic Information System (GIS). The basic unit of evaluation is the surveyed sections occurring in that system.

FILLING OUT THE DATA FORM AND DATA ENTRY

OBSERVER	3 spaces numeric; number is AGFD call-number (or assigned number)
MONTH	2 spaces numeric
DAY	2 spaces numeric
YEAR	2 spaces numeric

TOWNSHIP — 4 spaces numeric; FIRST 2 DIGITS ARE THE TOWNSHIP NUMBER, 3RD IS EITHER 0 (full range) OR 5 (½ range), 4TH DIGIT IS DIRECTION (1=N; 3=S)

Example T1N = 0101 (Remember: fill in leading 0)

RANGE — 4 spaces numeric; (FIRST 2 DIGITS THE RANGE NUMBER, 3RD IS 0 OR 5 IF ½ RANGE, 4TH DIGIT IS DIRECTION: 2=E; 4=W)

Example R5W = 0504 (Remember: fill in leading 0)

SECTION — 2 spaces numeric (Remember: fill in leading 0)

TERRAIN	2 spaces numeric
VEGETATION	2 spaces numeric
DEVELOPMENT	1 space numeric
FENCING	1 space numeric
WATER	1 space numeric
SEASONAL USE	1 space numeric (INFORMATION CODE ONLY)
JUXTAPOSITION	1 space numeric (INFORMATION CODE ONLY)

MOST CRITICAL FACTOR — 2 spaces numeric (INFORMATION CODE ONLY)

OVERALL RATING — 1 space numeric

1=High Quality with No Significant Problems
2=High Quality with Problems
3=Moderate Quality
4=Low Quality
5=Poor Quality
6=Evaluated as Unsuitable
0=Mapped as Poor or Unsuitable/Not Evaluated
9=Private Property/Access Denied

DECISION-MAKING (think about: can they see, then can they run, then can they eat)

Use attached sheets to help decide on:

Percent cover; forage quality of shrubs; season of grasses; major increasers-decreasers.

Make a preliminary rating based on **terrain** and **vegetation**, then modify the rating based on minor factors. Minor factors may either maintain or lower the overall rating. When in doubt, be conservative and lower the overall rating.

Decide what the most significant limiting factor is for the section, even if multiple problems exist. What 1 factor needs addressing the most in the section. Some factors we as managers cannot address, but note the problem anyway. Summarize the townships on the back of the form as you complete areas. Decide on the major issues for each township.

TERRAIN (T) CLASSES: MAJOR CATEGORY Most (>50-100%) of this section within the GMU is:

High Quality

1. **Flat to undulating** with slopes <5%; the rest of the section is generally <20% slope. The drainages are shallow and not very noticeable. No major steep-walled (>100% [45°]) canyons are present. Isolated small hills may alter the landscape, but if present, most are accessible to pronghorn. Landscape not rocky or boulder-strewn.

2. **Undulating to low, rolling hills** with slopes 5-10%, and has substantial areas <5%. Drainages are more noticeable and vegetation differences can occur on north and south-facing slopes. Again, no major steep-walled canyons are present, and if hills occur, only isolated small hills alter the landscape and are accessible to pronghorn. Landscape not rocky or boulder-strewn.

Moderate Quality

3. **Low to high, rolling hills** with slopes 10-20%. Flat to undulating areas also occur between hills. Ridgetops typically flat and extended. Drainages prominent with definite vegetation differences on north and south-facing slopes. No major steep-walled canyons are present. Some rocky areas or boulders may be present.

4. **Flat to undulating flats or mesa tops** with slope <5% as in Class 1, but within 400 m of a steep-walled slope from a canyon or mesa side. Limited rocky areas or boulders likely present.

5. **All <5% slope; virtually a flat surface.** Not undulating and has little or no isolated hills. Little topographic diversity occurs to modify plant growth, to act as fawning sites, or shelter from storms.

Low Quality

6. **Broken hills without extended ridgetops,** with slopes 10-20%. Limited areas with slopes <10%, typically between hills. Visibility obstructed by hillsides for most of the area. Drainages prominent and nearly surrounding the hills, and they are typically rocky. Rocky areas or boulders likely present.

7. **Broken hill with slopes 20-30%.** Little of the section <5% slope. Drainages prominent.

Poor Quality

8. **Slopes 30-40%.** Little of the section <5% slope. Drainages or small canyons prominent.

9. **Most unsuitable** either in form of major canyons with steep-walled sides, rocky or boulder-strewn field, or mountainous with slopes >40%. Isolated pockets of suitable terrain within the section.

Unsuitable Quality

10. **Virtually all has terrain >40% slope,** much is >100% slope, in form of mountains or numerous canyons; or **so rocky or boulder-strewn** that pronghorn would only pass through for dispersal.

VEGETATION (V) CLASSES: MAJOR CATEGORY   Most (>50-100%) of this section within the GMU is:

High Quality

1. **A rich shrub-grassland mix** (shrubs ≈5-20%) with most plants <24" [61 cm] tall. Sufficient shrubs ≥5 species of excellent or good forage plants for winter forage base: (1) distributed evenly throughout; (2) occur in clumped distribution, typically on north-facing slopes; or (3) if shrubs or succulents >24" [61 cm] tall occur scattered or in small clumps so general visibility not obstructed. Trees are absent or few (≈<1% cover, <2/acre [5/ha]) in clumps or along drainages. Grasses ≥5 species in mixture of cool and warm season perennials. Sufficient bare ground (>≈25% cover) for seasonal forb growth.

2. **A rich savanna shrub-grassland mix**. As above, except trees in greater densities (<≈5% cover, up to ≈8/acre [≈20/ha]) in scattered or clumped distribution; general visibility not obstructed.

Moderate Quality

3. **A reduced richness shrub-grassland mix** (≈5-20% shrubs). As in #1, except shrubs typically increasers in higher densities or less richness, but still short (<24" [61 cm]) so that general visibility is not obstructed. Grasses <5 species, and section dominated by only 1 or 2 species; increasers such as annuals may be co-dominant with perennials.

4. **A reduced richness savanna shrub-grassland mix**. As in #2, except shrubs typically increasers in higher densities and less richness, but still short (<24" [61 cm]) so that visibility is not obstructed. Grasses <5 species and area dominated by 1 or 2 species, increasers such as annuals may be co-dominant with perennials;

5. **A shrub-invaded grassland or savanna**; with short (<24" [61 cm]) shrub cover (20-30%) or tall (>24" [61 cm]) cover (10-20%), shrubs richness/diversity maybe low (<5 species); area dominated by 1 or 2 invader species (e.g., catclaw, snakeweed, shrub-form mesquite, rabbitbush, prickly pear); grasses may be dominated by increasers or annuals. Trees likely increasing in density. Visibility may be reduced somewhat by tall (>24" [61 cm]) shrubs-succulents.

6. **An open (≈5-20% cover) woodland, a rich shrub-grassland mix understory**. Understory grasses ≥5 species of excellent or good cool and warm season perennials; shrubs (≈5-30% cover) rich/diverse (≥5 species) and good forage species; Visibility is somewhat reduced, not in all directions; bare ground sufficient (>≈25% cover) for forb growth.

7. **An open (≈5-20% cover) forest, a rich shrub-grassland mix understory**. Understory grasses ≥5 species of excellent or good cool and warm season perennials; shrubs (≈5-30% cover) rich/diverse (≥5 species) and good forage species; Visibility is somewhat reduced, but not in all directions; bare ground sufficient (>≈25% cover) for forb growth.

Low Quality

8. **Bare ground >50%, an open desert-like** (low rainfall) of low-density xeric shrubs and succulents. Visibility has not been obstructed. Grasses not a prominent feature of the area. Vegetation predominantly <5 species of shrubs.

9. **An open (≈5-20% cover) woodland, a reduced shrub-grassland mix understory or with too many tall shrubs**; understory grasses typically 1 or 2 species of perennials. Shrubs (≈5-30% cover) less rich/diverse (<5 species) and likely of not good forage species; Visibility is somewhat reduced, but not in all directions. Bare ground predominant (>≈25% cover), but forb growth still likely. If a good understory exists, tall shrub density negates.

10. **An open (≈5-20% cover) forest, a reduced shrub-grassland mix understory**; understory grasses typically 1 or 2 species of perennials. Shrubs (≈5-30% cover) less rich/diverse (<5 species) and likely not good forage species. Visibility is somewhat reduced, but not in all directions. Bare ground predominant (>≈25% cover), but forb growth still likely.

11. **A severe shrub-invaded grassland or savanna**; shrub richness/diversity low. If shrubs short (<24" [61 cm]), density >30% cover, or if shrubs tall (<24" [61 cm]) density >20% and visibility a problem.

Poor Quality

12. **A closed shrubland** (usually much >≈30% cover, almost all >24" [61 cm] tall). Species richness is much reduced. General visibility is much reduced (i.e., chaparral).

13. **A closed woodland** (>≈20% cover, most >24" [61 cm] tall). Species richness is much reduced. General visibility is severely reduced.

14. **A closed forest** (>≈20% cover, most >24" [61 cm] tall). Species richness is much reduced. General visibility is severely reduced.

15. **A high-density, high-diversity desert** (low rainfall) of xeric shrubs and succulents. Tall desert trees and cacti reduce visibility.

16. **Agricultural lands.**

DEVELOPMENT/DISTURBANCE (D) CLASSES: MINOR CATEGORY Most (>50-100%) of this section within the GMU has:

High Quality

1. **Human disturbances unlikely most of the year.** No humans residing in the area, and no housing structures present. Minimal human disturbances such as recreational use (campsites, off-road vehicle [ORV] trails, etc.), livestock developments (corrals, feeding stations, etc.). Roads are few, typically only traces of 2-tracks.

2. **Minimal human disturbances most of the year.** No humans residing in the area, but abandoned structures may be present. Areas of seasonal use present, such as low-use primitive campgrounds (no facilities) or livestock holding-handling areas. Low-use dirt roads are typically present, but no high-use roads or paved roads present.

Moderate Quality

3. **Low human disturbances likely most of the year.** No permanent residences, but seasonal residences (cabins <5) may be present or developed campground (with facilities) may be present. Low to moderate use dirt roads likely present.

4. **Moderate human disturbance likely.** Isolated permanent residences (≈ 1/mile^2 [1/3 km^2]) or housing structures present or may have heavy seasonal camping use. Moderate to heavy-use dirt or gravel roads present, or high-density of dirt roads present. Highway may run through small part of section at 1 end.

Low Quality

5. **Human disturbances likely on a daily basis.** Scattered housing to mini-ranchettes, typically <1 per 3 acre [1/ha], or heavy year-round recreational use, or large commerical/industrial factility present. Heavy-use dirt, gravel, or paved roads running through middle of section.

Poor Quality

6. **High human disturbances on a daily basis.** Areas sub-divided with permanent housing on <3 acre [1 ha] plots or heavy recreational use (ORVs, shooting ranges, etc.). High-use gravel or paved roads numerous.

Unsuitable Quality

7. **Well-developed** housing, commerical, or industrial with a high-density road network present.

FENCING (F) CLASSES: MINOR CATEGORY **Most (>50-100%) of the section within the GMU has:**

High Quality

1. **No fencing**, thus pronghorn movements are unrestricted. May have fencing along less than 1 boundary (<1 mile [1.6 km]) such that movements are not restricted within or between sections.

2. **Electric fences**, but movements are likely unaffected. Typically a 2-strand system.

Moderate Quality

3. **Game standard or better barbed-wire fences** (smooth bottom strand at least 16-18" [41-46 cm] above ground), and numerous locations in which bottom strand is >18" [46 cm] occur. Pastures relatively large (≈0.5 mile² [≈1 km²]). Movements are only slightly impeded. Fencing exceeds 1 mile [1.6 km] in total.

4. **Barbed-wire fences without smooth bottom strand**, may have height modifications so that bottom strand typically <16-18" [41-46 cm] above ground. However, pastures are relatively large (≈0.5 mile² [≈1 km²]). Movements are impeded, and pronghorn must locate "spots" to cross under or learn to jump over. Fencing exceeds 1 mile [1.6 km] in total.

Low Quality

5. **Unmodified barbed-wire as in #4, but pastures are small** (<0.5 mile² [≈1 km²]) such that fences appear numerous. If woven-wire fences present, then crossings installed. Pronghorn movements are greatly restricted.

Poor Quality

6. **Woven-wire fences** (i.e., hog wire, chain link, field fence, chicken-wire, etc..) are present, and they are in pastures without crossings installed. Pronghorn movements are likely to be severely restricted.

Unsuitable Quality

7. **Fencing amount or structures severe** such that the area is virtually all unsuitable or unavailable for pronghorn. May be housing development, corral system, etc., causing the severe problem.

WATER (W) CLASSES: MINOR CATEGORY Most (>50-100%) of this section within the GMU is:

High Quality

1. **Less than 1 mile** [1.6 km] from numerous potentially usable water sources. Usable waters for pronghorn are those in good terrain not surrounded by woven-wire or log-corral fencing, or if barbed-wire the fenced area is relatively large and open. Waters may be a variety of types with most being open-earthen stock tanks. Vegetation around waters is minimal so visibility obstruction is not a problem.

Moderate Quality

2. **1-4 miles** [1.6-6.4 km] from water, and most waters accessible to pronghorn. Obtaining water is a minimal problem for pronghorn, with some travel necessary. Good fawning areas around waters not restricted.

Low Quality

3. **Greater than 4 miles** [6.4 km] from accessible waters, or waters in terrain or habitats less suitable for pronghorn. Obtaining water requires considerable travel or pronghorn must enter poor quality habitat to obtain, which increases mortality probability. Good fawning areas restricted because of the number of waters available.

Poor Quality

4. **A great distance to water**, greater than 10 miles [16 km] thus low year-round suitability for pronghorn because of water problems. Likely that fawning areas restricted because of poor water distribution.

NOTE: Water sources are not evaluated for year-round availability. Water locations may have been judged from topographic maps and may not have been field checked.

SEASONAL USE PROBABILITY: INFORMATIONAL CODE ONLY

Most (>50-100%) of this section within the GMU is:

1. **Year-round use likely.** Grasses and forbs for spring-summer use, and shrubs for winter use. Typically less than 7,000 ft [2,134 m].
2. **Summer Range.** Typically grassland community without substantial shrub component. Typically greater than 7,000 ft [2,134 m].
3. **Winter Range.** Typically a shrub-invaded grassland or low shrubland with minimal grasses. Typically lower rainfall area less than 7,000 ft [2,134 m].

JUXTAPOSITION: INFORMATIONAL CODE ONLY

Percent of High or Moderate habitat in this section, and its relationship to large expanses of other suitable habitat is:

1. Greater than 50%; its a single block and contiguous with other habitat.
2. Greater than 50%; its a single block but not contiguous, however, reasonable corridors available.
3. Less than 50%; its a single block and contiguous with other habitat.
4. Less than 50%; single block but not contiguous, however reasonable corridors available.
5. Broken patches; reasonable corridors available.
6. Few, small patches without reasonable corridors.
7. None noted.
8. Greater than 50%; its a single block but not contiguous and without reasonable corridors.

MOST CRITICAL LIMITING FACTOR: INFORMATIONAL CODE ONLY

The most critical factor of the habitat related to amount of pronghorn habitat use or potential use is:

1. Terrain too steep (>40%).
2. Terrain too rocky or too rough.
3. Tree densities too great.
4. Tall (>24" [>61 cm]) shrub densities too great.
5. Tall (>24" [>61 cm]) cactci/succulent densities too great.
6. Grass densities too great, ground cover poor for forb growth.
7. Grass-shrub species richness too low, forage diversity too low.
8. Major canyon dissects habitat, restricts or prevents movements to seasonal range.
9. Railroad, fenced on both sides dissects habitat.
10. Human development too great, ranchettes to urban conditions.
11. Human disturbance levels too great from recreational activities (i.e., high-use campsites, ORV, shooting range, etc.).
12. Human disturbance levels too great from high-use dirt or gravel roads.
13. Paved highway dissects habitat, restricts or prevents movements to seasonal range.
14. Poor fence structure.
15. Poor fence densities.
16. Poor water distribution.
17. Water distribution okay, but water inaccessible (too much vegetation, fencing problems, etc.).
18. Old juniper pushes--woodpiles obstructing pronghorn vision.
19. Shrub density too low.

OVERALL HABITAT RATING: THE END RESULT

Most (>50-100%) of the section within the GMU is:

1. **High quality habitat for pronghorn with no significant problems (T&V=1 or 2, Rest=1).**
   Major category of terrain must be High quality. Vegetation must also be High quality. All other categories rated the best (=1). High densities of pronghorn currently exist or could exist in the section for long periods of time.

2. **High quality habitat for pronghorn, but with problems that need to be addressed (T&V=1 or 2, Rest >1).**
   Major category of terrain must be High quality. Vegetation must also be High quality. Most other categories rated Moderate or better, but significant problem(s) exist that can be corrected. High densities of pronghorn currently exist in the section, or could exist in the section for long periods of time.

3. **Moderate quality habitat for pronghorn (T≤5, and/or V≤7).**
   Either or both major categories of terrain and vegetation are at least Moderate. Other categories likely in the Moderate or better ranges. Significant problems likely to be present. No category can be in the unsuitable range. Moderate densities of pronghorn currently exist in the section, or could exist over a long period of time.

4. **Low quality habitat for pronghorn (T=6 or 7, and/or V=8 to 11).**
   Either major categories (terrain or vegetation) with a Low or worse score. Other categories in the lower score class, with 1 likely to be a Poor score. No category can be in the unsuitable range. Low densities of pronghorn currently exist in the section or could exist over a long time period.

5. **Poor quality habitat for pronghorn (T=8 or 9, and/or V≥12).**
   Terrain or vegetation not likely even Moderate, and other categories in the lower classes. Severe problems exist, however, no category can be in the unsuitable range. Scarce populations of pronghorn currently exist in the section, or could exist in the section over long periods of time.

6. **Unsuitable quality habitat for pronghorn (T=10 or D=7 or F=7).**
   Any category in the unsuitable class overrides all other categories, even if in the High or Moderate classes for most categories. It is unlikely that any pronghorn could exist in this section for a long period of time.

0. **Mapped as Poor or Unsuitable/Not evaluated**
   GIS processing identified as area consisting of unsuitable vegetation >3.2 km from grassland or large area >20% in Digital Terrain Elevational Database. This category not rated in the field.

9. **Access by Landowner/permittee not granted/Not evaluated**
   Denied access on or through private property. These sections not rated.

NOTE: **Initial score based on Terrain and Vegetation; then if Development/disturbance, Water, or Fencing scores ≥5 and the Overall rating <4 (High or Moderate), then Overall score is knocked down by 1.**

RATING OUTSIDE OF THE GUIDELINES

If you encounter situations in which you believe the rating system does not adequately assist in determining the appropriate quality of the surveyed sections, rate each section accordingly and justify (list reasons) the overall score on the back of the data sheet.

APPENDIX C. Photographic Examples of Rated Pronghorn Habitat.

Figure C1. Terrain was flat to gently, rolling hills (T=1), and vegetation was a reduced species richness shrub-grassland (V=3). Shrub species richness was lacking, so Overall quality was Moderate (3).

Figure C2. Terrain was gently, rolling hills with isolated hills (T=1), and vegetation was a species rich shrub-grassland (V=1). Elevation was summer-only range, but fencing (F=6) restricted access, lowering quality to Moderate (3).

APPENDIX C. (continued)

Figure C3. Terrain was flat to gently, rolling hills (T=1). Vegetation outside fences was a species rich shrub-grassland (V=1) and was a shrub-invaded grassland (V=5) inside the fences. Sections outside were Excellent quality (2) and those inside were Moderate (3).

Figure C4. Terrain was flat to gently, rolling hills (T=1), and vegetation was a reduced species richness savanna (V=4). Water was accessible (W=1) to the section. Overall quality was Moderate (3).

APPENDIX C. (continued)

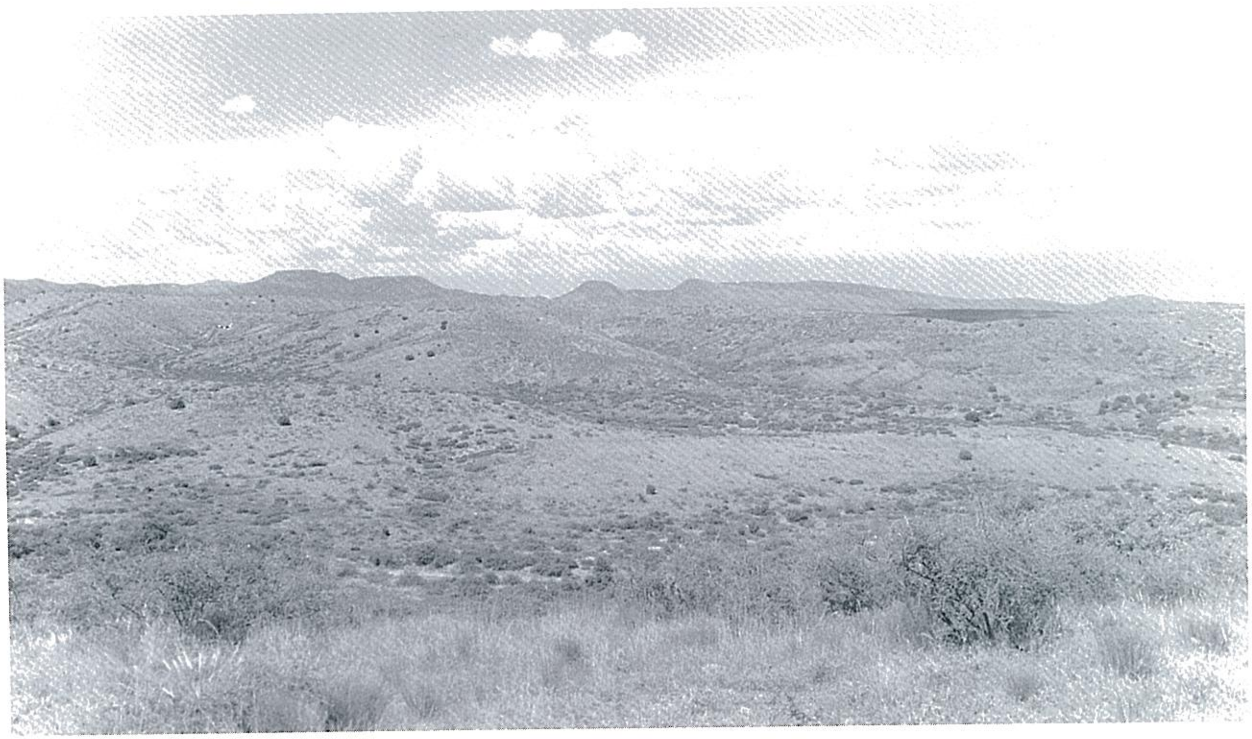


Figure C5. Terrain was low to high, rolling hills (T=3), and vegetation was a severe, shrub-invaded grassland (V=11). Shrub densities lessened Overall quality to Low (4).

Figure C6. Foreground section was flat to gently, rolling terrain (T=1), but vegetation was a severe, shrub-invaded grassland (V=11), lowering Overall quality to Low (4).

APPENDIX C. (continued)

Figure C7. Development/disturbance was high on a daily basis (D=6), dropping this gently, rolling hills (T=1) and species rich savanna (V=2) from Excellent to Moderate (3) quality.

Figure C8. Downed juniper trees in this open woodland restricted visibility (V=9). Terrain was undulating to low, rolling hills (T=2). Overall quality was Low (4).

APPENDIX C. (continued)

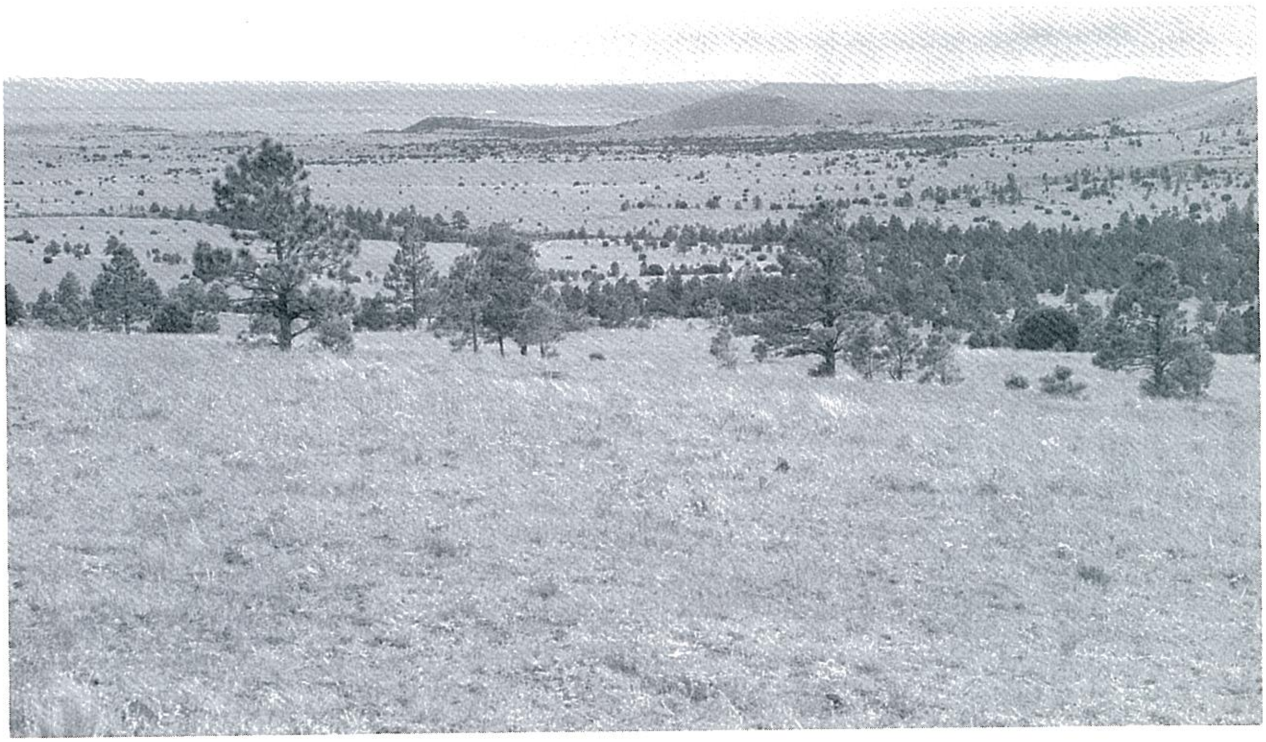


Figure C9. Terrain was flat to gently, rolling hills with scattered hills (T=1). Tree densities were increasing in the reduced species richness savanna (V=4). Overall quality was Moderate.

Figure C10. Terrain was undulating to low, rolling hills (T=2), and vegetation was mostly a reduced species richness shrub-grassland (V=3). The well-developed housing (D=7) rendered the section Unsuitable (6).

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Ockenfels, R.A., C.L. Ticer, A. Alexander, and J.A. Wennerlund. 1996. **A Landscape-level Pronghorn Habitat Evaluation Model for Arizona.** Arizona Game and Fish Dep. Tech. Rep. 19, Phoenix. 50pp.

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Key Words: antelope, *Antilocapra americana*, Arizona, assessment, evaluation, habitat, pronghorn, rating system

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