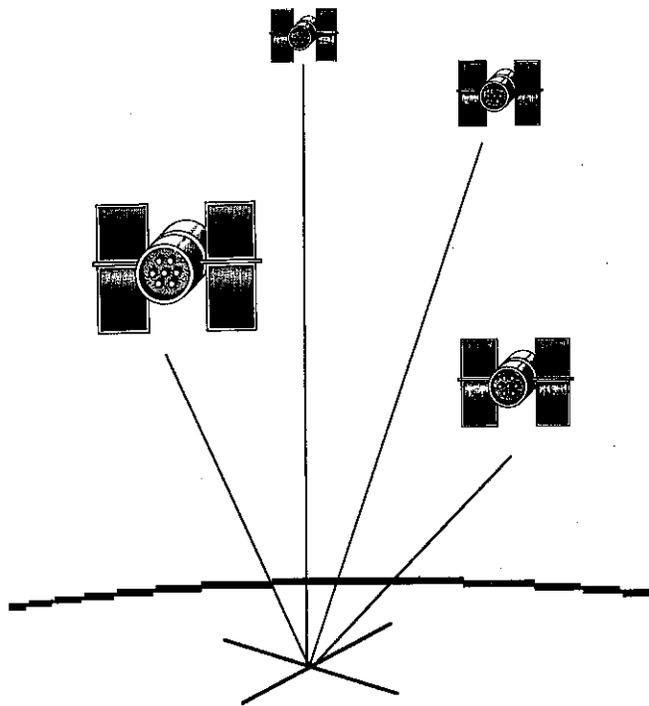


MAPPING MOUNT GRAHAM RED SQUIRREL MIDDENS USING GLOBAL POSITIONING AND GEOGRAPHIC INFORMATION SYSTEMS

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INTRODUCTION

The Mount Graham red squirrel (*Tamiasciurus hudsonicus grahamensis*) (MGRS) is endemic to the Pinaleno Mountains of southeastern Arizona. The Pinalenos have been isolated from other mountain ranges for approximately 10,000 years. This has allowed the MGRS to be secluded from other red squirrel populations for hundreds of generations. The MGRS resides in upper elevation mature to old-growth associations in mixed conifer and spruce-fir stands (USFWS 1993). The Pinalenos represent the southernmost range for this habitat type in the United States (Brown 1984, Hoffmeister 1986).

The MGRS was listed by the U.S. Fish and Wildlife Service (USFWS) as endangered on June 3, 1987 (USFWS 1993). It is also included on the Arizona Game and Fish Department's (AGFD) list of *Threatened Native Wildlife in Arizona* (AGFD 1988). The MGRS Recovery Plan (USFWS 1993) serves as a guideline for MGRS management. Exact locational information for MGRS middens (food caches) is crucial to conservation of the species and to managing use of the public lands the MGRS occupies atop the Pinalenos.

From 1987-1991, MGRS middens were referenced by biologists marking each midden location on a 7.5 minute topographic map, then manually transferring this mark to a base map of all middens. For many years, this was the best method available, although middens were sometimes mapped incorrectly, resulting in many hours of searching the wrong area to relocate them. The primary objective of this project was to relocate all MGRS middens and reference them with Global Positioning Systems (GPS) technology (satellite-based locational information), thus incorporating the data into a computerized Geographic Information System (GIS) and resolving most relocation problems.

METHODS

Field surveys to GPS-reference middens were conducted between July 15, 1993 and August 30, 1995. GPS data were collected using a six channel Pathfinder Basic Plus™ receiver, external antennae, and a range pole (Trimble Navigation, Ltd., Sunnyvale, California). GPS Pathfinder Professional™ software (Pfnder) (Trimble Navigation, Ltd.) was used to correct the GPS data and to predict satellite availability for each field trip. GPS-referenced midden points on current GIS-generated maps were collected using site-specific settings (Table 1) that necessarily deviated slightly from GPS manual recommendations.

Field	Settings
Position Fix Mode*	3D (4 satellites)
Maximum PDOP	08
Coordinate System	Latitude/Longitude
No. Points Read	200
Clock/Time Zone	UTC - 7
Units of Measure	English
Altitude Reference	MSL
Communications Protocol	XMODUM
Dynamics Code	Land

* Position Fix Mode: Exceptions were made when collecting GPS points on trails and roads. Auto 2D/3D Position Fix Mode was used to acquire continuous GPS readings while walking or driving. 2D readings were accepted to avoid data gaps over long stretches.

Groups of middens were visited daily. For each midden, a data sheet was used to record: midden number (confirmed by a permanent tag affixed to a tree adjacent to the midden), GPS filename, midden status (disappeared, remnant, transiently active, not immediately active, active), sex and age of squirrel seen in midden, number of GPS points, position fix mode recorded in, date, start time, and weather conditions.

Middens were GPS referenced at the tagged or marked tree whenever possible. When dense canopy cover or other unknown interferences (i.e. atmospheric activity, canyon walls, removed/inactivated satellites) occurred at the site, GPS referencing was conducted within 20 feet of the tagged tree. One of two measures was taken to optimize satellite signal reception:

1. The nearest possible point to the tag tree was GPS referenced, then the distance between that point and the tag tree was measured and a compass bearing was taken.
2. If another GPS referenced midden was nearby, the distance between the known GPS referenced tag tree and the unread tag tree was measured, then a compass bearing was taken.

When using these techniques, the midden was mapped at the appropriate distance and direction from the GPS file, using GIS commands.

Field data were differentially corrected using data obtained from the Coronado National Forest (CNF) GPS Pathfinder Community Base Station Bulletin Board (provided through Wallace Craig, CNF) and AGFD's Base Station. The CNF Base Station is on top of the Federal Building in Tucson, Arizona. The AGFD Base Station is at the AGFD Phoenix office. These stations lie less than 300 miles from Mount Graham, and are thus within GPS operating manual minimum-distance requirements for accurate point corrections. Pathfinder software was used to complete corrections and manipulate data.

A database file was set up to enter vital midden information, including: name, corresponding University of Arizona MGRS Monitoring Program midden number (if any), corrected GPS points, forest composition, forest stage, slope, aspect, exposure, and comments.

ARC/INFO (Environmental Systems Research Institute, INC., Redlands, California) was used to combine digitized topographic maps of Webb Peak and Mount Graham, Arizona quadrangles (The Land Information Technology company, Ltd., Aurora, Colorado) with the database file to produce GIS-generated midden maps.

RESULTS

Due to topographic map errors, clarification was needed for trails, roads, and perimeters marked on the maps. These features were GPS referenced in the position fix mode of 2D/3D, which allowed for a more complete file. Trails that were GPS referenced are as follows: Webb Peak to Chesley Flat; Webb Peak to the Corrals; Ash Creek; Ash Creek to Webb Peak; Shannon campground to Heliograph; and the trail into upper Turkey Flat.

Roads that were GPS referenced are: Grand View Peak; Webb Peak Road; the fire road on Webb Peak; the Corrals; crossroads of the Bible Camp road, swift trail, and the Columbine Work Center entrance; access road to telescopes; fire road in Plain View; and Grant Hill.

The perimeters of the CNF Columbine Work Center, the Astrological site, and the newly cleared area on Emerald Peak to the east of the University of Arizona/Steward Observatory telescopes were also GPS referenced.

Using the most recently updated base midden map, 710 MGRS middens were GPS referenced (Table 2). However, 18 middens could not be GPS referenced, because they could not be relocated using their previously mapped locations. These middens have been classified as "not found" in the MGRS GIS midden database maintained by AGFD for cooperating agencies. This database can be provided in the following electronic formats: ARC/INFO export file; MOSS export file; AutoCad DXF file; MapInfo; and dBase.

Upper Turkey Flat posed a problem in regard to GPS-referencing middens. High canyon walls there blocked out signals from satellites, thus few middens have been GPSed in this area. After

several trips into the area, and reviewing the GPS data generated, we have concluded that this area cannot be successfully GPS mapped.

Table 2. Mount Graham red squirrel midden locations referenced by Global Positioning Systems (GPS).			
Area	Number of Middens GPSed	New Middens GPSed, Untagged	Not Found
Merrill Peak	32	3	0
Chesley Flat	32	10	3
Webb Peak	81	3	3
Swift Trail	26	0	0
Soldier Creek	4	1	0
Mill Site	38	3	2
Columbine	125	2	6
Bible Camp	102	2	1
Emerald Peak	24	0	1
Hawk Peak	40	0	0
BS Area	37	0	0
Mt. Graham	50	0	0
Plain View	38	0	0
Grant Hill	13	0	0
Treasure Park	7	1	0
PE Area	4	0	1
Heliograph	15	0	1
SO Area	12	0	0
Turkey Flat	30	0	-
Total	710	25	18

CONCLUSIONS

The GPS/GIS MGRS midden maps produced in this project were first field tested during the 1994 fall midden survey, and then again during the 1995 spring and fall surveys. They proved to be more accurate than the topographic maps that were used previously. This enabled survey teams to spend less time searching for middens, which resulted in a shorter, more efficient, and less costly survey.

RECOMMENDATIONS

Each summer, new middens found on the spring and fall surveys from the previous year should be field checked, tagged, and GPS referenced. This would allow for a current and up to date map of the squirrel middens.

The mountain should be swept to update the current midden map. This would allow for an accurate file of known middens, whether they are classified as active, inactive, or removed. These classifications are defined as follows:

"Active" middens have signs of recent activity such as digging, fresh feeding sign, current caching, fluffy texture, or presence of a squirrel.

"Inactive" middens show no sign of recent activity, such as no digging, no fresh sign of feeding, debris on top of the midden, and no squirrel sighting.

A "removed" midden must be classified as disappeared and inactive for at least three years, or composted and inactive for at least four years. A removed midden will be kept in the database and surveyed every five years.

A third symbol could be added to the map to clarify which middens have been removed. This would allow all middens to remain on the map but distinguish between those that are active in the database and those that have been removed.

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