Natural Resources and Environmental Issues

Volume 2 Mapping Tomorrow's Resources

Article 12

1-1-1993

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Foster, Dan A. (1993) "Position of GPS in wildlife and habitat mapping," *Natural Resources and Environmental Issues*: Vol. 2, Article 12. Available at: http://digitalcommons.usu.edu/nrei/vol2/iss1/12

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The Position of GPS in Wildlife and Habitat Mapping

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Abstract

Global positioning system (GPS) technology is being implemented by the Department of Defense and is becoming generally available. Portable, lightweight, low-cost receivers give a rapid readout of location to within 100 feet in a few seconds. The geometry of the satellite GPS system and of the ground-based Long Range Navigation (LORAN) system is described. Examples are given of the use of the LORAN system to track black bears in the Spanish Fork area of Utah, using radio collars. This use provides an effective method of monitoring habitat usage and seasonal activity patterns. GPS is effective in field mapping because it provides navigation control for transects, permits precise recovery of study sites, and permits verification of habitat maps. A habitat study of Gambel's quail in southwest Utah provides a good example of this application. GPS is also used to provide control for the rectification of photogrammetric information, greatly increasing the efficiency and cost-effectiveness of aerial survey. Examples of Hopi rattlesnake and Gila monster studies in southern Utah are presented, illustrating the use of GPS to link field studies to studies of earth-resources satellite data. Combining these in a GIS environment saves countless hours of time, reaps large dividends in dollars, and proves to be an effective tool in managing natural resources.

INTRODUCTION

Global positioning system (GPS) technology is making major changes in the way information is gathered for mapping purposes. With rapid storage, automated retrieval, and high accuracy, GPS is making revolutionary changes in traditional field surveying and data acquisition. Geographic information system (GIS) technology combined with GPS data collected in field studies can be rapidly manipulated to model past, present, and future conditions for various management purposes. Wildlife and habitat information is also being affected by GPS usage. Using GPS is now faster and less expensive for data gathering and implementation into GIS coverages for wildlife information and management purposes.

This paper will attempt to give a brief overview of GPS and a few of the present and potential uses of this Star Wars technology in wildlife and habitat mapping and management.

OVERVIEW OF GPS

The U.S. Department of Defense (DoD) developed GPS technology to assist in military navigation and national defense. With the development of low cost and lightweight receivers, GPS technology is now available for use by virtually anyone.

As seen in Figure 1, the GPS system consists of three components (Hurn 1989, GPS Report 1992).

SPACE COMPONENT

The space component, when complete, will consist of a constellation of twenty-one active and three reserve satellites positioned approximately 12,600 miles above the earth. The satellites will be organized in six different orbital paths that will give any point on the earth a clear view of at least four satellites twenty-four hours a day. Each satellite has a unique code for identification by GPS receivers.

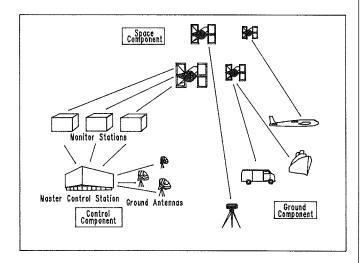


Figure 1. GPS configuration (GPS Report 1992)

CONTROL COMPONENT

The control component consists of a master control station in Colorado Springs, Colorado, a group of monitor control stations, and upload antennae. The monitor control stations track satellites continuously and feed the recorded information back to the master control station. Using this information, the master control station calculates precise orbital information for each satellite and sends this information to the upload antennae. This information is then relayed to the satellites daily for corrections.

USER COMPONENT

The user component consists of the various land, sea, and air receivers that allow reception of precise location, velocity, and time information.

GPS is based on the principle of triangulating a position on earth by measuring its distance to a grouping of satellites. If, as seen in Figure 2a, a position is X number of miles from satellite one, it is somewhere on an imaginary circle with a radius of X miles and centered on the satellite. If the position is Y number of miles from satellite two, it is somewhere on the circle where the spheres from the two satellites intersect (Figure 2b). By using a third satellite, only two points in space can be true for the position since the intersection of that satellite's sphere, with the two others, gives only two possibilities (Figure 2c). Since one of these possible locations is usually distorted in time or space, it is discarded by the processor in the GPS; and the correct position is displayed on the screen. A fourth satellite also solves the problem for the exact position and can serve to measure the elevation of the receiver.

As with most systems, there are limitations and

errors that exist in GPS technology. Factors such as signal integrity, signal accuracy, satellite ephemeris error, and atmospheric refraction errors are handled by GPS hardware and software. One that is handled by the user is GPS signal reception. GPS requires direct reception of signals from satellites. Satellite signals travel in straight lines and cannot penetrate water, soil, or other solid objects. This means that anything that would block a line of sight could also block satellite signals. GPS, therefore, cannot function under water, underground, under heavy vegetative canopy, or under similar situations.

WILDLIFE AND HABITAT MAPPING

MAPPING WILDLIFE

In managing wildlife, it is necessary to know where individual species or groupings of species are located. Various methods have been developed and used for study of individuals or populations of species. The most primitive method of recording this information has been to observe the species and then locate and record the site on hard-copy maps. For many situations, this has been adequate but has presented the problem of tracking locations of multiple species on a single map with the confusion created by the thousands of sightings collected or the management of multiple maps for the same area.

The other problem introduced is that of the mapping accuracy of the individual sighting or population parameter. The national map accuracy standard of a U.S. Geological Survey 1:24,000 quadrangle is

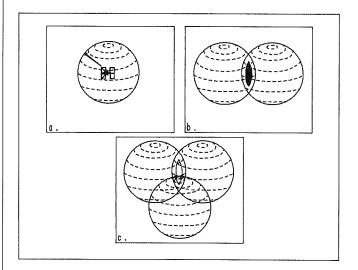


Figure 2. GPS triangulation (Hurn 1989)

approximately 40 feet. The width of the section lines on a standard quadrangle is approximately 40 feet also. Any drawing by the user on the map with a line width of that size introduces that amount of error. Greater line widths introduce greater error; that is, if the width of the line drawn by the mapper is twice the width of the section line, the introduced error is a minimum of plus or minus 80 feet but could be much more, assuming the base map had a 40-foot map accuracy error. Additional error is created in the automation of that information by digitizing.

By using precise time and distance measurements, GPS can accurately position to within 100 feet. By using a GPS base station receiver positioned at a surveyed location, the readings can be corrected based on differential averaging to within 6 to 45 feet (Kruczynski 1990). For most situations in wildlife and habitat delineation, these accuracies exceed accuracies obtained by commonly used mapping conventions.

Mapping wildlife presents many situations in which GPS can be of extreme value. Wildlife sightings and observations can be located immediately and more accurately. Export of location information to a GIS format takes place in automated modes, eliminating human error in transcribing, typing, or digitizing. Sightings and observations in GIS files become valuable sources of data for managing individual species and also for delineating the habitat in which the species is found. This is particularly important in regard to threatened, endangered, or sensitive species. In many cases, the sighting of one species indicates the possible presence of other associated species in the area.

The location of critical feeding, breeding, or resting areas can be enhanced by the use of GPS. For years the use of telemetry has been an important tool in the tracking of species and identification of important habitats. By placing a microtransmitter on a study animal, its movements can be observed in a general manner. A directional antenna is used to receive the signal from the transmitter. When the signal is located, a compass bearing is taken and plotted to give the direction of the animal from the antenna. By using two antennae, the intersection of the compass bearings would be the approximate location of the animal (Koeln and Cook 1984). Airborne antennae simply circle a continual reading to take a general triangulation.

The use of Long Range Navigation (LORAN) has made this process simpler. LORAN is a ground-based navigation system that emits radio signals within groupings of stations or chains. The Western United States coastal chain is seen in Figure 3.

By triangulating the receiver position in the chain, general locations can be obtained for navigation purposes. This method has been used in wildlife

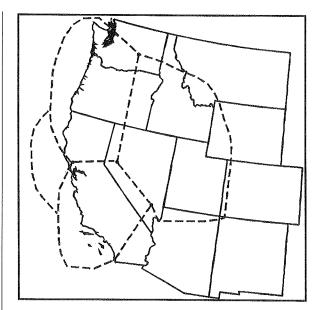


Figure 3. Western U.S. coastal LORAN chain (MIECO 1987)

mapping for quite some time with generally good results. Various sources of error exist in the system, but probably the most significant in wildlife uses is known as "secondary phase lag." Since the signal transmission is in a straight line and the surface of the earth is curved, anything that is not in line of sight will suffer a delay in signal reception as shown in Figure 4. Additional delay may occur due to absorption of the signal by the surface of the earth.

On ground-based telemetry, this may be negligible except in areas of high relief where the reading can become extremely skewed (Lachapelle and Townsend 1991). With receivers in automobiles, boats, or aircraft, this becomes critical. Because of the time delay in signal reception, the point at which the signal is recorded may be as much as a few seconds from where the signal is received and updated. If the phase lag is extremely long, the position displayed on the readout can be many seconds old. The old readout coupled with the speed of travel could amount to a significant distance from the desired position, introducing a large error. In multichannel GPS receivers, the update rate of signal reception is no longer than one second, giving precise location information.

An example of telemetry in Utah is the tracking of black bears (*Ursus americanus*) for seasonal movements and location of winter den sites. By triangulating the microtransmitter signals with LORAN, a general area can be identified for the den site. Surveys must then be conducted on the ground to find specific locations, such as dens. LORAN is capable of locational accuracies of about 500 feet (Lachapelle and Townsend 1991, Langley 1992). Thus, a survey area of 250,000 square feet or 5.75 acres would be the result. With uncorrected 100-foot GPS readings, the

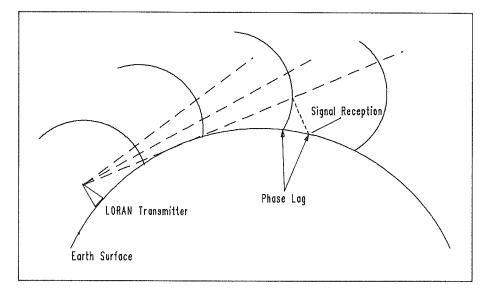


Figure 4. Secondary phase lag (Lachapelle and Townsend 1991)

area would be 10,000 square feet or .23 acres. By placing a receiver on the animal and relaying the location to another receiver, the movements of the study animal can be tracked (Figure 5) and could even be displayed interactively on a computer monitor. The possibilities of monitoring animal movements from on site or remote locations and mapping habitat usage by seasonal, daily, or even time of day are endless. Even the speed of movement could be measured.

The U.S. National Park Service conducted a study of desert tortoises (*Gopherus agassizii*) in the Joshua Tree National Monument in California. The objectives were to locate individual animals and den sites within the tortoises' habitat and to be able to return to the dens at later dates with high accuracy to

monitor population and habitat trends. The area of the study was large, and two study alternatives were available. The first was to mark off a study grid with stakes and string so that precise locations could be defined. Each section of the grid would be 100 square meters, and the whole area would take 10,000 stakes. Such a grid was time prohibitive from the outset. The second alternative was to attach GPS receivers to individual tortoises and to monitor movements to locate den sites. Once dens were located, they were flagged and GPS readings were averaged to give precise locations. The results of the study were exciting in that individual tortoises and dens were easily located, the information was automated into a GIS, and an intensive, automated database was developed. For each tortoise, locations were entered

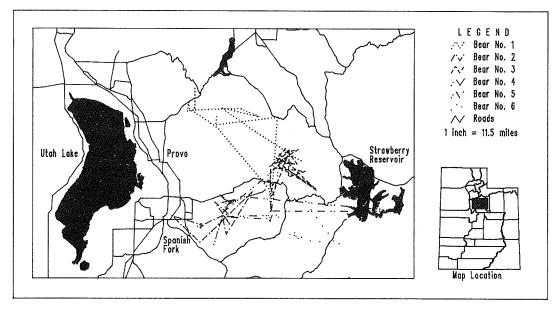


Figure 5. Bear locations from transmitter signals

describing size, weight, sex, and den information. Additionally, a color image of the tortoise was scanned and stored in a display facility that could be displayed on demand (Freilich and Moon 1991).

New advances in software are allowing the collection and automation of location attributes in the field. By attaching a personal computer to the GPS unit in the field, attributes can be entered "on the fly" as locations are taken. The use of personal computers means that forms for data collection can be automated and field data entered into GIS format as it is collected in the field. Additionally, information from other monitoring equipment, such as water, air, and soil gauges, can be automated directly from the sensor to the GIS with accurate location information, virtually eliminating the need for costly data transcription.

traverses by providing quality-control checks. When returning to the field study site, there is no traverse needed to get from control points to project sites, thus reducing traverse distances in the field. GPS also provides a means of controlling geodetic distortions in large field traverses. With conventional surveying, in order to compute the desired coordinates, the surveyor must transform field work from the surface of the earth to the ellipsoid and then transform again to the coordinate system. GPS gives the surveyed data measured in the ellipsoid. The surveyor need only translate data in one step to the coordinate system desired (Wurz 1991).

Delineation of wildlife distributions can be improved using GPS to spatially locate environmental parameters. Many species are mapped based on where they have been seen and where there is suit-

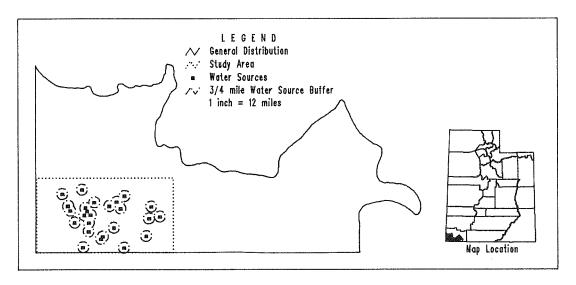


Figure 6. Gambel's quail model

Mapping Habitat

Field mapping of habitat types, timber stands, land ownership boundaries, or other areas is easily facilitated via GPS. The technology provides automated recording of field coordinates, traverse completion times, and a means of calculating areas. In addition the data are easily downloaded into GIS-ready files. In all surveys, the time interval of location recording can be varied to accommodate the speed of travel; that is, locations could be recorded every ten to fifteen seconds for surveys on foot and every second for aerial surveys, depending on the location accuracy desired.

The use of GPS offers an inexpensive way to traverse descriptions of metes and bounds on the ground, as well as to locate easements, waterways, water sources, structures, and other items.

In many situations, GPS aids in field-study

able habitat. This use of GPS, however, may be too broad for many species since there are conditions that may keep them from using the entire habitat. Gambel's quail (*Callipepla gambelii*) is a good example. A study in southwest Utah (Nish 1964) showed that although good habitat, such as cover, forage, and terrain, was available throughout most of the study area over two-thirds of the birds studied were found within one-half mile of water sources. These sources existed in the form of springs, streams, cattle troughs, and guzzlers (man-made catchments provided for wildlife water sources). By taking GPS readings at these water sources and buffering the locations to appropriate distances in a GIS, wildlife distributions can be further refined as shown in Figure 6.

Mapping wildlife distributions based on denning/ nesting areas and dispersal patterns is also enhanced by GPS. By taking accurate locations of den sites for species such as the Hopi rattlesnake (*Crotalus viridis* nuntius) and entering these into a GIS, models of dispersion, as shown in Figure 7, can be generated. This model is based on approximated distance of dispersion, habitat-use preference, and use of den sites on a yearly basis.

One of the most exciting uses of GPS is in rectification of photogrammetric information to be used in GIS. Aerial photographs, videography, and remotely sensed satellite imagery all contain distortions by

taking an image of a curved surface and placing it on a flat plane. GPS can provide ground control points to give vertical and horizontal correction to help in reshaping and coordinating the image. By taking readings on the ground at locations easily recognized in the photos or by taking readings on the image, the control is established. The more control points found, the greater the accuracy of rectification. This provides a cost-effective means of mapping areas espe-

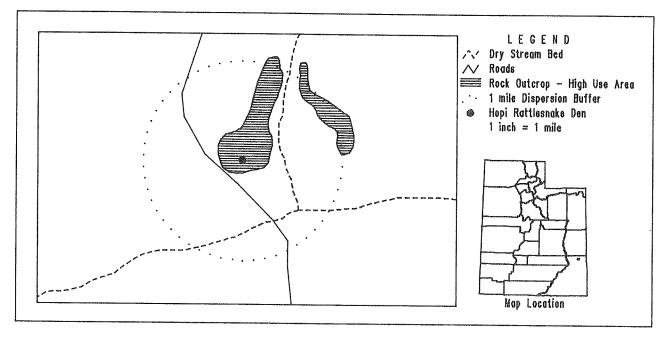


Figure 7. Hopi rattlesnake dispersion model

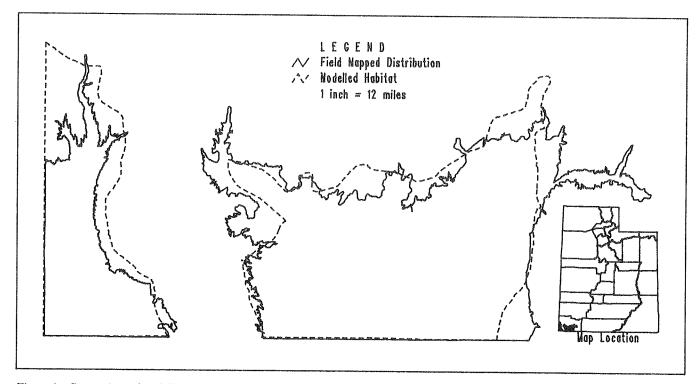


Figure 8. Comparison of modelled and mapped banded Gila monster distribution

cially in remote or poorly known areas (Hough 1992).

Using remote sensing technology, base vegetation cover maps are being developed in Utah and in many other states that will allow preliminary predictions of where individuals or groups of species may be found on an ecosystem basis. These cover maps are being developed in a cooperative project known as the Gap Analysis procedure (Foster and Schrupp 1991, Scott et al. 1990). The vegetative and land-cover types defined for mapping were selected on the basis of their ability to be seen via remote sensing and their compatibility with a regional Gap Analysis program. Georeferencing in many cases is being done by using existing GIS databases and GPS locations from field surveys.

To begin delineation of cover types, a classification scheme was developed that would fit the needs of a regional perspective and still suit the needs of resource agencies in each state. The basic component of the scheme is the dominant vegetative type that can be grouped with other types to create an ecotype (Foster and Foster 1987).

The Thematic Mapper (TM) images used for this study record information on seven spectral bands. For the Utah study, bands one to five and seven were used to obtain as much reflectance value as possible. The high gray-level values allowed increased potential to define vegetation-cover types (Craighead et al. 1985).

The TM data is stored in a raster (or grid) system with each cell or pixel containing its own reflectance value based on what was seen on the ground. Groups of pixels, usually no less than four to five, with similar reflectance are identified so that their values are not "drowned out" by contiguous groupings. By using an "unsupervised" algorithm, the basic spectral class groupings are obtainable on a statewide basis. These groups can then be identified as to cover types of interest. Field surveys were conducted using GPS to record fixed X-Y coordinates within homogeneous cover types and to establish a training for reflectance values of pixels in the TM data.

This method also provided elevation information for further refinement of data characteristics. The relief in Utah is from warm desert shrub at about 2,000 feet in southwest Utah to the alpine tundra above 13,500 feet in the Uintah Mountains of northeastern Utah (Armstrong 1977, Welsh et al. 1987). Since the reflectance values of some dominant cover types are so similar (for example, lodgepole pine vs. Colorado blue spruce), elevation, slope, or aspect information was needed to designate those cover types. The GPS information obtained in the field was used in conjunction with automated 1:24,000 scale Digital Elevation Models (DEM) to aid in distinguishing subtleties between those cover types.

By using various information on wildlife ecological

relationships, these cover-type maps can then be used to generate potential distribution maps for individuals and groups of species. Mapping many of these species has never been attempted because information, such as that described, has not been available. This will be of real benefit to wildlife management, especially on ecological parameters. An example is shown in Figure 8 for the banded Gila monster (*Heloderma suspectum cinctum*) in southwestern Utah. This model shows how closely the modelled distribution from vegetative parameters coincides with the actual mapped distribution obtained from field studies.

SUMMARY

As can be seen from this brief look at a few applications, GPS can be used for a multitude of projects to aid and enhance mapping and to delineate wildlife and habitat. The use of GPS will no doubt increase as more applications are conceived, defined, and tested. Probably the most prominent limitations to the technology are (1) establishment of standards of acceptable GPS position accuracy and credibility, (2) full implementation of the GPS system by the DoD, and (3) the continual upheaval brought on by the DoD's use of Selective Availability (SA) and its attendant problems.

Still, it is safe to exclaim and promote GPS as the ultimate field tool for collection of spatial data, whether for wildlife, habitat, or other endeavors. The combination of GPS and GIS to capture, model, and analyze spatial information will save countless hours of time, will reap large dividends in dollars, and, if used correctly, will prove an effective tool in the decision-making process of managing our natural resources.

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