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Testing releasable GPS radiocollars on wolves and white-tailed deer

Samuel B. Merrill, Layne G. Adams, Michael E. Nelson, and L. David Mech

Abstract We tested prototype GPS collars on 8 free-ranging wolves (*Canis lupus*) and 3 white-tailed deer (*Odocoileus virginianus*) for varying periods between February and August 1997. We programmed the 920-gm collars to make a location attempt 6–96 times per day. The collars were designed to be remotely released from the animal and the data were then downloaded to a desktop computer. The collars produced 47–1,549 locations each during 11–41 days; locations were successful in 26–95% of the attempts ($\bar{x}$ = 70%). Eight collars released successfully. Three collar-release failures were caused by condensation. Two collars had GPS antennas that were improperly attached and did not collect data. Life was as long as, or longer than, expected in 4 collars, less than expected in 5 collars, and unknown in 2 collars. Limitations of this type of collar include brief life if programmed at short location-attempt intervals (≤1 hr) and possible drop-off failure. Nevertheless, the large volume of data we collected with no field telemetry effort demonstrates the potential for this type of GPS collar to answer questions about movements of medium-sized mammals.

Key words Alaska, GPS, location data, Minnesota, movements, satellites, telemetry, white-tailed deer, wolves

Satellite technology has been used in wildlife studies for many years, but primarily with transmitting collars (Warner 1967, Buechner et al. 1971, Kolz et al. 1980, Fancy et al. 1988) rather than receiving collars (Rempel et al. 1995, Moen et al. 1996). Transmitting collars transmit to satellites which transfer the data to earth. Receiving collars calculate and store positions with data from an internal Global Positioning System (GPS) that scans 24 earth-orbiting satellites. The satellites continuously broadcast radio signals, and a GPS receiver must simultaneously receive signals from ≥4 such satellites to determine its 3-dimensional position (latitude, longitude, and height).

Stand-alone GPS receivers are usually accurate to within 40 m 50% of the time and to within 100 m 95% of the time (Hurn 1989). This suboptimal accuracy is a result of code dithering called "selective availability" introduced into the satellite signals by the U.S. Department of Defense. Much of this error can be removed through differential correction, which can increase accuracy to within 2-5 m (Trimble Navigation Ltd. 1992). However, differential correction is an intensive process and may be worthwhile only when research questions cannot be answered with uncorrected data (Moen et al. 1997, Rempel and Rodgers 1997). Global positioning system collars are about 10 times more expensive than conventional radiotelemetry collars, but for an equivalent data-collection protocol the overall cost is dramatically reduced (Rogers and Anson 1994, Ballard et al. 1995), and the GPS collars we tested are reusable. Costs of

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GPS collars are roughly equivalent to costs of satellite collars.

Global positioning system collars weighing 1.8 kg and allowing remote data downloading have been tested, but they could only be used on large animals such as moose (*Alces alces*; Rempel et al. 1995, Moen et al. 1996). To retrieve the collar, one had to recapture the animal.

We tested a 920-gm GPS collar on free-ranging wolves and deer. It was designed to be remotely released but was incapable of remotely downloading the data. We chose this collar because it was the only GPS collar light enough (<1100 g) to be used on our study animals. It also had the following desirable characteristics: large numbers of possible locations per collar, high accuracy of locations obtained, regularity of data collection intervals, and flexibility of data collection programming. Also, drop-off collars have been demonstrated to be particularly useful for addressing some research questions (Mech and Gese 1992). This study evaluated success of the collar's longevity and numbers of locations obtained rather than accuracy of locations. Accuracy of GPS collars under a range of conditions has been discussed elsewhere (Rempel et al. 1995, Moen et al. 1996).

Study sites

We tested the GPS collars in 3 sites: Camp Ripley National Guard Training Site, Little Falls, Minnesota, (46° N, 95° W); Denali National Park, Alaska, (63° N, 151° W); and the Superior National Forest in Minnesota (47° N, 91° W).

Camp Ripley is a 21,400-ha parcel on the prairie-forest transition zone in central Minnesota. The terrain in this area is generally flat, and the major cover is northern hardwood forest (primarily oak [*Quercus* spp.], aspen [*Populus* spp.], and birch [*Betula* spp.]) interspersed with large open areas (grasslands, wetlands, and military firing ranges) comprising about 45% of the total (Brezinka 1995). Deciduous trees were without leaves during data collection. Temperatures ranged from -22 to 9°C.

The Alaska study area lies just north of Mount McKinley in Denali National Park and Preserve, including the foothills of Mount McKinley as well as spruce bogs, open eskers, riverbottoms, and tundra flats (Mech et al. 1998). Temperatures during the study varied from -7 to 23°C.

The Superior National Forest study site is gently rolling, and the vegetation is a mixture of maturing forests, various aged conifer plantations, and clearcuts. Aspen, paper birch (*Betula papyrifera*), balsam fir (*Abies balsamea*), red pine (*Pinus resinosa*), and jack pine (*P. banksiana*) predominate in the lowlands (Mech and Gese 1992). Temperatures in the Superior National Forest area were -17 to 20°C during the study, and deciduous trees were leafless for some of the tests and fully leafed for others.

Methods

Prototype GPS collars were designed and constructed by Advanced Telemetry Systems, Inc. (Isanti, Minn.; Fig. 1). The collars weighed 920 g each, including a molded plastic box (8.2 x 11.9 x 5.4 cm) containing the GPS unit, microcomputer with nonvolatile memory, batteries, VHF transmitter, and receiver, as well as the drop-off device (weight: <20 g) and belting of the capture-collar (Mech and Gese 1992). The GPS boards were constructed by Garmin, Inc. (Olathe, Kans.). They operated in 12 parallel channels and were L1-C/A code compatible. The GPS antenna (the size of a standard spool of thread) was situated on top of the collars. Each collar emitted a VHF signal at 60 beeps/minute for standard radiotracking. Each collar had a mortality mode. Accuracy of the GPS boards was tested under open sky prior to collar deployment. On 3 tests with 58, 53, and 56 locations, uncorrected error was 76.5 m, 72.5 m, and 62.9 m, respectively ($\bar{x}$ = 70.6 m). This measure of error is the "2DRMS" value, or 2 * square root ([SD of X errors]^2 + [SD of Y errors]^2).

We attached the collars to a desktop DOS computer and programmed them to make location attempts at 1 per 15 minute, 1 per 30 minute, 1 per 45 minute, 1 per hour, or 1 per any number of hours specified. The GPS device turned on at the programmed intervals and turned off after each attempt. Each location attempt lasted until a fix was obtained or 96 sec. If no location was recorded, the GPS collar

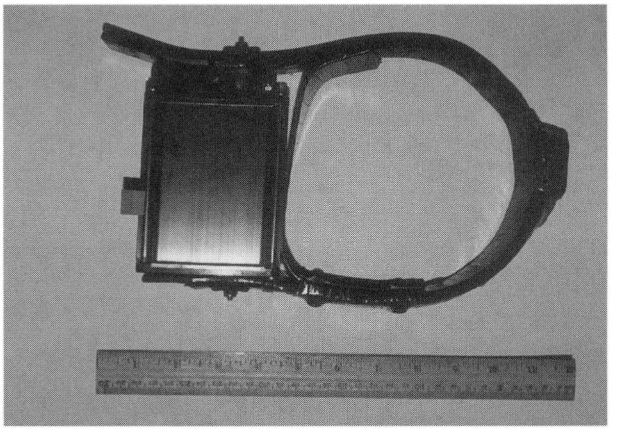

Fig. 1. Global Positioning System (GPS) radiocollar tested on wolves and white-tailed deer. Molded plastic box is 8.2 x 11.9 x 5.4 cm; the entire collar weighs 920 g.

tried again in 15 min and 30 min. If all 3 attempts failed, further attempts were not made until the next programmed interval. If an attempt was successful, the VHF signal produced was 3 single beeps and a double beep; otherwise single beeps only were transmitted. ATS estimated that the collars could receive and record 1,200 ± 400 locations each, depending on energy used during each location attempt.

A transmitting device (triggering transmitter) allowed communication with the collars to determine status of the GPS batteries and to release the collar at any time (Mech and Gese 1992). If no such signal was sent, the collars were programmed to drop off automatically about 65 days after GPS battery expiration. None of our collars dropped off in this fashion. Once a collar was released, the VHF signal was transmitted at 30 beeps per minute for about 25 days. When battery levels were too low to make a GPS location attempt, the VHF signal pulse rate changed from 60 beeps per minute to 45 beeps per minute.

After we retrieved the collars, location data stored in the collar was downloaded to a personal computer (in ASCII). Downloaded data included time, date, location (latitude and longitude or UTM), identity of satellites used, and 2 indices of the estimated accuracy of the locations (whether the locations were 2-dimensional or 3-dimensional and PDOP, the Positional Dilution of Position; Logsdon 1992).

We placed GPS collars on 4 wolves (23–39 kg) in February 1997 at Camp Ripley, on 3 white-tailed deer (58–76 kg) in the Superior National Forest during April 1997, on 2 wolves (32 and 35 kg) in Denali in May 1997, and on 2 wolves in the Superior National Forest in July 1997 (Table 1).

We estimated the expected longevity of each collar (Table 1) for all sampling rates from the manufacturer's estimate that each collar was capable of making 1,200 ± 400 location attempts. However, the relationship between location-attempt rate and GPS life is not linear. It is influenced by variable VHF and microprocessor current drain between location-attempt intervals of different lengths and by increased current drain per GPS attempt at longer intervals. These are therefore approximations of GPS life. Actual life will probably be 10–20% lower for collars programmed to attempt locations at intervals >3 hours, and closer to estimated values for collars programmed to attempt locations at <3 hours (based on calculations by the manufacturer).

The manufacturer estimates that with no GPS location attempts, the VHF transmitter and microprocessor current would deplete the battery in 512 days. However, with 1 GPS location attempt per day and retries of once per week, for example, they estimate the GPS battery should last 354 days; thereafter, only the VHF transmitter would operate.

Table 1. Information on 11 releasable GPS collars placed on 8 wolves and 3 deer in 3 study areas (Denali Natl. Park, Alas.; Superior Natl. Forest, Minn.; and Camp Ripley, Minn.) in 1997.

Species	Area[a]	Date deployed	Last collection date	Location attempt rate	Number of locations	Success[b] (%)	Expected life (days)[c]	Actual Life (days)	Successful drop-off
Wolf	Ripley	20 Feb	13 Mar	4/hr	1,477	76	12.5 ± 4.1	19.5	Yes
Wolf	Ripley	20 Feb	5 Mar	1/hr	265	87–98	25.0 ± 8.2	11.4[d]	Yes
Wolf	Ripley	20 Feb	8 Mar	1/hr	327	76–82	50.0 ± 16.4	13.2[d]	No
Wolf	Ripley	20 Feb	14 Mar	2/hr	647	72–81	50.0 ± 16.4	21.1[d]	No[e]
Deer	SNF	5 Apr	15 Apr	1/hr	0	0	50.0 ± 16.4	unknown	Yes
Deer	SNF	6 Apr	14 May	1/hr	677	63–74	50.0 ± 16.4	38.0	Yes
Deer	SNF	10 Apr	17 Apr	1/hr	0	0	50.0 ± 16.4	unknown	Yes
Wolf	Denali	14 May	30 May	4/hr	1,310	85	12.5 ± 4.1	16+	Yes
Wolf	Denali	14 May	31 May	4/hr	1,549	95	12.5 ± 4.1	17+	No
Wolf	SNF	16 July	4 Aug	8/day	47	26–29	135 ± 44.0[f]	20	Yes
Wolf	SNF	30 July	8 Sept	6/day	143	47–58	160 ± 52.4[g]	41	Yes

[a] Ripley=Camp Ripley National Guard Training Site, Little Falls, Minn.; SNF = Superior National Forest, Minn.; Denali = Denali National Park, Alas.

[b] Minimum is based on number of extra attempts the GPS made to obtain a location. Maximum is based on total number of locations the GPS was programmed to obtain. Collars with attempt rates at 4/hour have only one number because "retry" intervals are also programmed intervals.

[c] Based on 1,200 ± 400 attempts per collar as predicted by ATS, Inc.

[d] Short life caused by condensation inside battery box.

[e] The drop-off mechanism on this collar failed; the collar was retrieved when the wolf was trapped.

[f] Based on 1,200 ± 400 attempts per collar, minus 10% for VHF current drain as predicted by ATS, Inc.

[g] Based on 1,200 ± 400 attempts per collar, minus 20% for VHF current drain as predicted by ATS, Inc.

Results

Of the 11 prototype collars tested, 9 produced 47–1,549 locations for 11–41 days, and 8 (not all the same collars as those that recorded locations) released successfully (Table 1). The 3 collars that failed to drop were on wolves and were collected by capturing the animals. Success rates of GPS location attempts for the 9 collars that collected data were 26–95% and averaged 70% (Table 1). The 2 lowest location success rates (0%) were from collars on deer in the Superior National Forest. In these 2 collars the connection between the GPS antenna and the collar housing was not secure. Six of the 11 collars both gathered data and dropped off upon command. These collars collected 47, 143, 265, 677, 1,310, and 1,477 locations. We provide 1 type of graphic output possible with GPS data (Fig. 2).

Approximations of GPS collar life varied from 12.5–50.0 days, while actual GPS life lasted 11–38 days (Table 1), including 2 collars tested in Denali that recorded reliably for 16–17 days and were then removed for convenience while still recording data. Actual longevity of these 2 collars went undetermined.

For successful locations, the mean time to determine the locations was 63 seconds in the Camp Ripley area, 83 seconds for the 2 deer in the Superior National Forest before leafout, 91 seconds for the 2 wolves during summer, and 57 seconds in Denali. Positional Dilution of Position values can range from 0.00 to 9.00, with lower values theoretically representing more accurate estimates of location; in this study mean PDOP for all locations was 3.75 (range = 1.10–9.00). However, although PDOP is theoretically a good index of locational accuracy, the GPS collar manufacturer has verified that selective availability error is usually large enough to nullify the effectiveness of PDOP as an accuracy index. Nevertheless, PDOP is probably still a good index for differentially corrected data.

The collars we tested were prototypes, and we uncovered various flaws during their application. Their VHF signal strength was variable, with strength of some signals being about 1/3 to 1/2 that of conventional collars in the forested areas, although not in Denali. At Camp Ripley, 2 of 4 collars stopped emitting a VHF signal about a week after they were deployed and stopped taking fixes about 900 location attempts sooner than the batteries would have allowed. This problem was later attributed to moisture on the microprocessor boards, because of faulty sealing of the housing. Condensation also caused the "squib" used to release the collars (Mech and Gese 1992) to fail on 2 Camp Ripley collars and 1 Denali collar. We did not find evidence that these collars failed from behavior of the wolves (e.g., chewing or swimming). We retrieved these collars by recapturing the wolves through helicopter darting and foothold trapping.

Errors in collar software produced unrecognizable beep patterns in 2 collars. This problem made it difficult to determine whether location attempts had been successful until the collars were retrieved.

As noted above, on 2 collars the GPS antenna leads were too short, so once the collars were placed on deer, the leads disconnected, resulting in zero locations. The third collar was placed on a larger deer; the antenna lead held, but the GPS antenna pointed off to the side. Thus the battery expended too much power per attempt and died prematurely, although the collar still produced 677 locations.

Discussion

Our tests demonstrated the potential of the 920-gram, releasable GPS collar for research on medium-sized animals such as deer and wolves. The number of fixes we obtained in just 2 weeks from the 2 Denali wolves would have taken 20 years to collect at the usual rate of about 1 aerial radiotracking location per week. Similarly, conventional ground radiotracking for the deer would have required 18 hr of tracking per day for 38 successive days. The informational value of location data collected over 2 greatly different periods varies, and each method produces different types of information. However, the GPS collars gathered location data much more quickly and in much greater quantity than previous techniques allowed. Furthermore, the ability of the GPS collar to record location data both day and night could add a new dimension to movement studies. Because collection of short-interval data reduces collar longevity, some questions (e.g., about home ranges and seasonal movements) may be best addressed with long-interval data. Short-interval data may be most appropriate for questions about movements during denning, dispersal, or other temporally restricted periods.

We exposed several flaws in the prototype collars, as was the intent of the tests, and the manufacturer corrected the flaws (as indicated by subsequent use of new collars). Collars that made fewer successful attempts than others were probably more often under thick canopy (Moen et al. 1996). Thus additional tests are needed in thick cover during summer. Another factor influencing number of locations is animal activity. When an animal is sleeping or resting, for example, the GPS antenna may

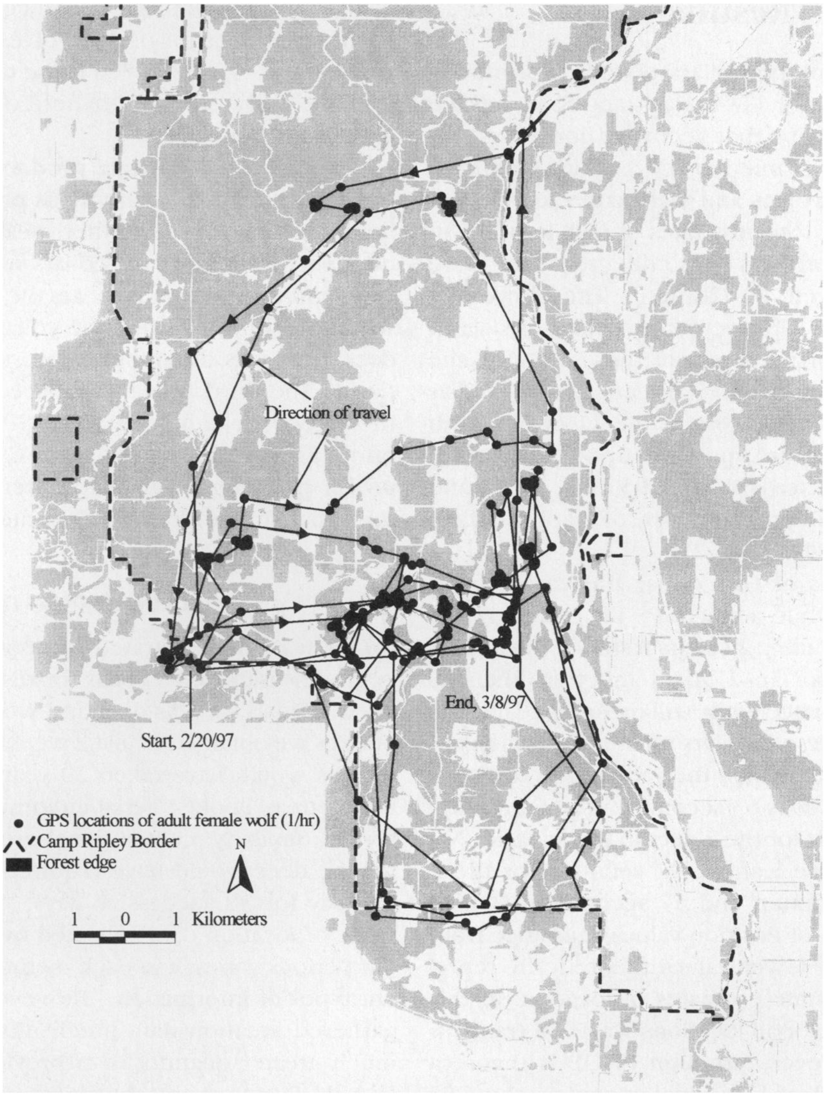

Fig. 2. Movement data (327 locations) collected by GPS collar on a breeding female wolf from 20 February to 8 March 1997 at Camp Ripley, Minnesota. Global Positioning System location-attempt rate was set at 1/hr, and success rate was 76% during this period. Dots represent actual locations; lines merely connect consecutive points.

point away from the sky. Such a position causes GPS batteries to expend more power per attempt, which shortens GPS life.

The manufacturer indicates that, as GPS batteries weaken, the likelihood of a successful location attempt is constant until the batteries reach a low level. At that point, enough power exists to determine locations, but many failed attempts may occur in sequence. This explains why some collars had longer than expected life (Table 1); toward the end of data collection in these collars, ≤1.3 days passed without successful locations, followed by a few additional successful locations.

We found no evidence that the GPS collars we tested were too heavy for the wolves or deer, and other researchers have used collars weighing 1.08–1.22 kg on wolves (Ballard et al. 1995). Nevertheless, we caution that the heavier the collar, the greater the chance that the collar may affect the animal's activity or movement patterns. We recommend that manufacturers reduce GPS collar weights for wolves to <600 gm because standard VHF collars of that weight have been used for decades with no apparent effects on the wolves or the data.

The primary limitation of GPS data collection at brief intervals is the short period of collar operation. This is likely to improve with advances in battery technology and new software that may conserve battery life. Furthermore, by programming the GPS collar to collect only 1 location per day, one can increase its theoretical potential life to about a year.

Another problem involves possible failure of the collar-release mechanism. Because an entire collection of data may depend on the reliability of this release device, manufacturers should strive to include a redundant release system. Ideally, a GPS collar would collect, store, and transmit data in real time.

For more efficient data collection, manufacturers should thoroughly waterproof collars, test software in the field, and use VHF circuitry that maximizes signals. Ideally, GPS collars would allow remote downloading of data (Rempel et al. 1995) and would incorporate a recapture device allowing researchers to change batteries or collars (Mech et al. 1984, 1990; Mech and Gese 1992). However, the latter 2 additions would require more weight, so they must await developments that reduce weight of the entire package.

Until further refinements and technological advances are made, the 920-gm, releasable GPS collar we tested will prove valuable to many researchers studying the movements and activity of medium-size mammals.

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Literature cited

Ballard, W. B., D. J. Reed, S. G. Fancy, and P. R. Krausman. 1995. Accuracy, precision, and performance of satellite telemetry for monitoring wolf movements. Pages 461–467 *in* L. N. Carbyn, S. H. Fritts, and D. R. Seip, editors. Ecology and conservation of wolves in a changing world. Canadian Circumpolar Institute, Occasional Publication 35.

Brezinka, J. 1995. Land Condition Trend Analysis: Installation Report. Minnesota Department of Natural Resources, Camp Ripley Series Report 7.

Buechner, H. K., F. C. Craighead, Jr., J. J. Craighead, and C. E. Cote. 1971. Satellites for research on free roaming animals. BioScience 21:1201–1205.

Fancy, S. G., L. F. Pank, D. C. Douglas, C. H. Durby, G. W. Garner, S. C. Amstrup, and W. L. Regelin. 1988. Satellite telemetry: a new tool for wildlife research and management. U.S. Fish and Wildlife Service, Resource Publication Number 172.

Hurn, J. 1989. GPS: a guide to the next utility. Trimble Navigations, Limited, Sunnyvale, California.

Kolz, A. L,. J. W. Lentfer, and H. G. Fallek. 1980. Satellite radio tracking of polar bears instrumented in Alaska. Pages 743–752 *in* C. J. Amlaner, Jr., and D. W. MacDonald, editors. A handbook on biotelemetry and radio tracking. Pergamon Press, Oxford, London.

Logsdon, T. 1992. The Navstar Global Positioning System. Van Norstrand Reinhold, New York, New York.

Mech, L. D., L. G. Adams, T. J. Meier, J. W. Burch, and B. W. Dale. 1998. Wolves of Denali. University of Minnesota Press, Minneapolis.

Mech, L. D., R. C. Chapman, W. W. Cochran, L. Simmons, and U. S. Seal. 1984. A radio-triggered anesthetic-dart collar for recapturing large mammals. Wildlife Society Bulletin 12:69–74.

Mech, L. D., and E. M. Gese. 1992. Field testing the Wildlink capture collar on wolves. Wildlife Society Bulletin 20:249–256.

Mech, L. D., K. E. Kunkel, R. C. Chapman, and T. J. Kreeger. 1990. Field testing of commercially manufactured capture collars on wild deer. Journal of Wildlife Management 54:297–299.

Moen, R., J. Pastor, and Y. Cohen. 1997. Accuracy of GPS telemetry collar locations with differential GPS. Journal of Wildlife Management 61:530–539.

Moen, R., J. Pastor, Y. Cohen, and C. C. Schwartz. 1996. Effects of moose movement and habitat use on GPS collar performance. Journal of Wildlife Management 60:659–668.

Rempel, R. S., and A. R. Rodgers. 1997. Effects of differential correction on accuracy of a GPS animal location system. Journal of Wildlife Management 61:525–529.

Rempel, R. S., A. R. Rodgers, and K. F. Abraham. 1995. Performance of a GPS animal location system under boreal forest canopy. Journal of Wildlife Management 59:543–551.

Rodgers, A. R., and P. Anson. 1994. Animal-borne GPS: tracking the habitat. GPS World 5:20–32.

Trimble Navigation, Limited. 1992. GPS Pathfinder System General Reference. Trimble Navigation, Limited, Sunnyvale, California.

Warner, D. W. 1967. Space tracks. Pages 221–228 *in* I. W. Knoblack, editor. Readings in Biological Science. Second edition. Appleton-Century-Crofts, New York, New York.

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