SATELLITE TRACKING OF GOLDEN EAGLES FROM AUTUMN MIGRATION STUDY SITES IN NEVADA AND NEIGHBORING AREAS

JEFF P. SMITH, PHD

HawkWatch International, Salt Lake City, UT

Current: H. T. Harvey & Associates, Los Gatos, CA

jsmith@harveyecology.com

INTRODUCTION

The Golden Eagle (*Aquila chrysaetos*) is a partial migrant, with northern populations largely migratory and southern populations comparatively sedentary. In North America, previous banding and radio-tracking demonstrated the largely sedentary nature of adults and typically limited dispersal distances of juveniles associated with breeding populations in central California, Utah, Washington, Idaho, and Colorado. Breeding adults and some immature eagles are also relatively sedentary in southern California; however, recent satellite tracking by the Wildlife Research Institute demonstrated that some juveniles from San Diego County disperse/migrate sizeable distances northward after fledging, as has been demonstrated for some southern-latitude Bald Eagles (*Haliaeetus leucocephalus*) and Red-tailed Hawks (*Buteo jamaicensis*).

Variation in migration volume across long-term monitoring sites in western North America illustrates high abundances of northern migrants n Alberta and Montana, but with numbers dwindling quickly farther south. Carol McIntyre used satellite tracking to document long-distance migrations of juvenile Golden Eagles from Denali National Park in Alaska and use of a broad distribution of winter ranges from west-central Canada, south through the Rocky Mountains and western Great Plains, and into northern Mexico. Together these data suggest complex patterns of population mixing across western North America.

Understanding the temporal and spatial aspects of population mixing is critical for interpreting trends in long-term migration counts and assessing how human activities and habitat change may affect these trends. Documenting the details of a species' movement ecology, including regional variation in migration geography, behaviors and timing, and habitat use, also is critical for identifying region-specific conservation needs and priorities. For Golden Eagles, in particular, these and other facets of movement ecology, including passage timing and the locations of seasonal aggregations, are a growing concern in relation to the rapid development of wind-energy generation facilities across the species' range in North America.

I report the temporal and spatial movement patterns of a sample of Golden Eagles captured and outfitted with satellite-received transmitters (PTTs) at five autumn migration study sites in the western United States. I describe the results of this 10-year effort, emphasizing the following objectives:

OBJECTIVES

1) Document regional variation in migration behavior, movement geography, and the timing of annual movements.

2) Identify commonly used migration corridors and winter and summer ranges to help focus habitat-oriented conservation priorities.

3) Increase understanding of population mixing at different migration monitoring sites to improve interpretation of trends in long-term migration counts.

4) Document causes of mortality.

FIELD METHODS

Outfitted 33 Golden Eagles from October 1999 to October 2008 within three regional migration corridors (see figure above to right).

Most deployments in Nevada and New Mexico; sampling highly biased towards hatch-year (HY) males (male: 22 HY, 4 SY, 1 ATY; female: 4 HY, 1 SY, 1 ATY).

All PTTs attached using backpack-style body harnesses and weighed <3% of eagle mass.

31 battery powered PTTs: conventional ARGOS location data every 2 days during migration periods and every 4 days during non-migration periods. Expected battery life 43 months ± 30%.

2 GPS-enabled, solar-powered PTTs: daily GPS location data; deployed in 2006 (NM) and 2008 (WY).

Attempted to recover most motionless PTTs, within weeks to months.

Evaluation of dead eagles generally limited to on-site inspection for obvious trauma or maladies.

LOCATION DATA COLLECTION AND PROCESSING

Used ARGOS data collection and location system, and Douglas (2010) ARGOS-filter algorithm to exclude auxiliary-class locations that failed to meet minimum standards for retention.

Initial filtering retained 23,581 data points, including 2% GPS, 63% ARGOS standard-class, and 35% ARGOS auxiliary-class locations – dataset for all quantitative analyses.

Best-of-duty-cycle locations – used to graphically represent overall movements.

DATA SUMMARIES AND ANALYSES

To evaluate regional differences in movement ecology, I classified individual eagles as:

- **LONG-DISTANCE MIGRANTS**: moved seasonally in roughly N–S directions, across one-way distances >1500 km, and between summer and winter ranges in geographically disparate regions.
- **REGIONAL RESIDENTS**: generally remained year-round within the same physiographic province, including a few short-to-moderate distance (<1000 km one-way) directional migrants.

To investigate differences in range-wide movements, I calculated two distance metrics:

- **MAXIMUM LINEAR EXTENT OF MOVEMENTS** within a given seasonal or annual period, as the maximum distance (km) separating all relevant tracking locations
- **TOTAL DISTANCE TRAVELED** within an annual cycle, estimated as the sum of all travel-segment distances calculated using Douglas (2010) processing algorithm.

To investigate differences in seasonal movement patterns, I classified winter/summer ranges as:

- **RESTRICTED**: eagle always remained within 150 km of its first seasonal location
- **MARGINALLY RESTRICTED**: some temporary excursions extended beyond 150 km, but core range remained the same
- **NON-RESTRICTED**: eagle shifted overall range more than 150 km one or more times during season.

To investigate route and range fidelity and ecoregion-level habitat associations, I used simple map-based evaluations to identify coarse-scale patterns, believing that the low spatial and temporal precision of most location data precluded more quantitative analyses:

- **MIGRATION-ROUTE FIDELITY**: seasonal or interannual migration routes generally remaining within 200–300 km of one another.
- **SEASONAL RANGE FIDELITY**: seasonal ranges overlapping broadly among years.

PTT PERFORMANCE

Tracking periods ranged from 2–53.5 months.

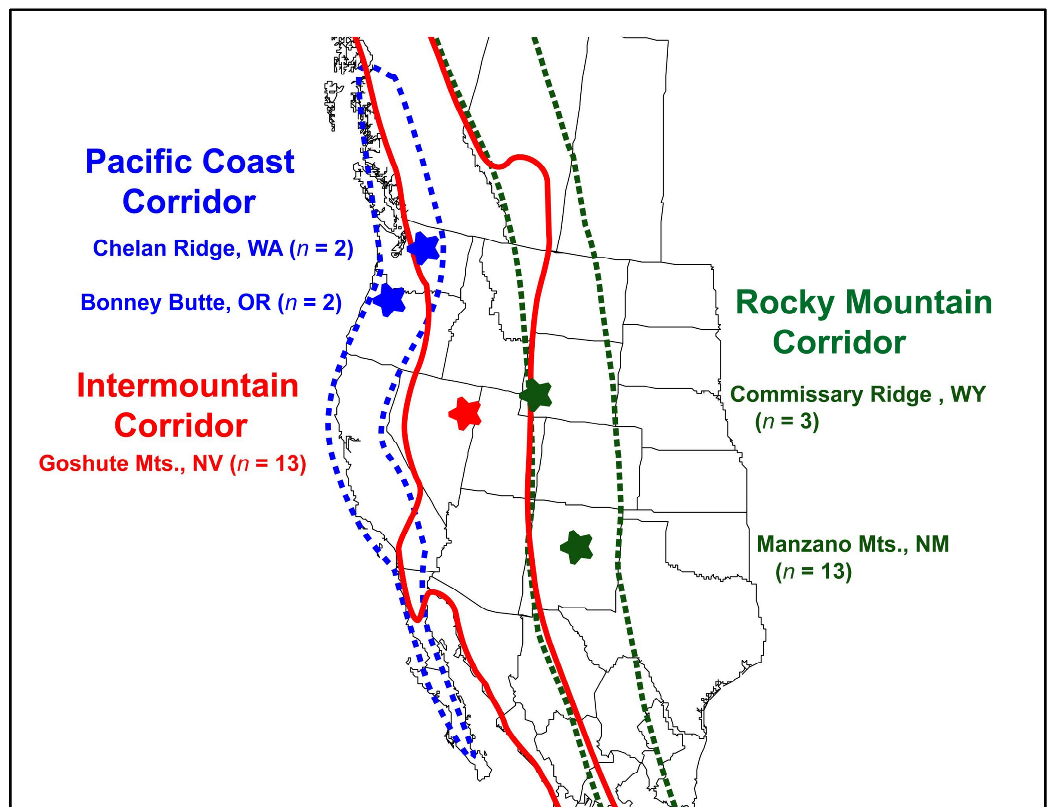
Thirteen (39%) battery-powered PTTs failed within <19 months, well before the expected minimum transmission lifespan of 30 months.

Voltage data confirmed 46% due to premature battery failure; all sensor data normal prior to other premature failures during autumn and winter.

Recoveries confirmed 13 mortalities, including two eagles that were alive when their PTT batteries failed (1 at 9 months and 1 at 37 months) but were subsequently found dead.

Four eagles were still alive when their PTT batteries failed within an expected time frame.

Manuscript soon to be in review at The Condor



PTT Deployment Sites Within Three Regional Migration Corridors

LONG-DISTANCE MIGRANTS VS REGIONAL RESIDENTS

Overall: 48% long-distance migrants, 30% regional residents, and 21% uncertain.

Regional residents move less, earlier in spring, and later in autumn

Maximum linear extent of movements by 9 regional residents averaged 83% shorter (547 ± 295 km) than for 13 long-distance migrants (3,276 ± 1,595 km).

Five regional residents averaged 66% shorter overall annual travel distances (3,819 ± 1243 km) than 5 long-distance migrants (11,075 ± 3,255 km).

Regional residents began spring movements on average 40 days earlier, ended them 66 days earlier, and took 30 fewer days to complete them than the long-distance migrants.

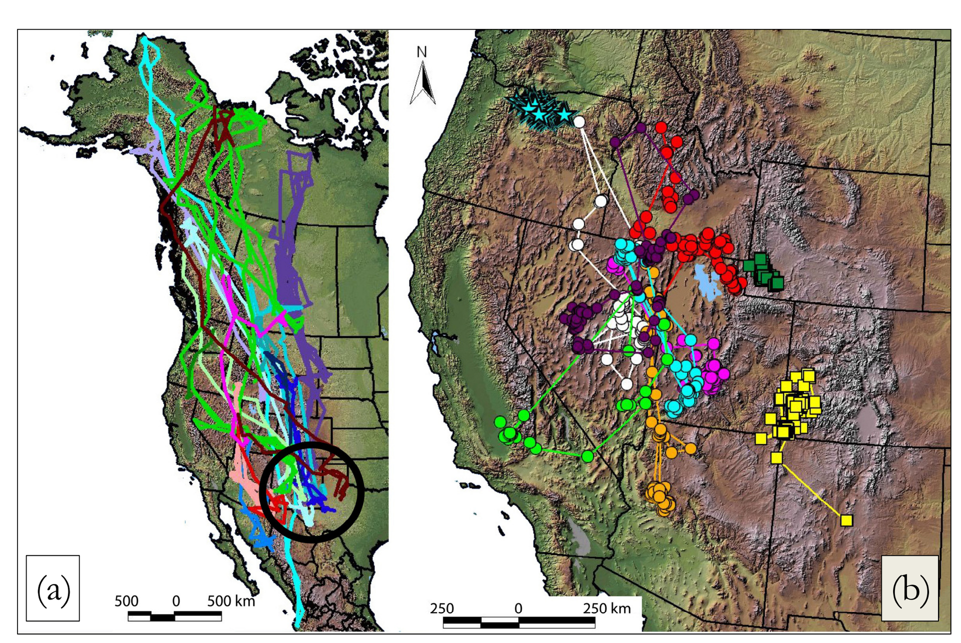
Regional residents began autumn movements on average 42 days later , ended them 16 days earlier, and took 43 fewer days to complete them than the long-distance migrants.

Proportional representation varies among migration corridors

Intermountain (n = 11): **64% regional residents**, 36% long-distance migrants.
Rocky Mountain (n = 11): 18% regional residents, **72% long-distance migrants**.
Pacific Coast (n = 4): 25% probable regional residents, **75% long-distance migrants**.

Regional resident?	Migration Corridor: Pacific Coast	Intermountain	Rocky Mountain	Total
Yes	1?	7	2	**10**
Unknown[1]	0	2	5	**7**
No	3	4	9	**16**
Total	4	13	16	**33**

[1] Eagles not tracked long enough to confirm migration pattern; i.e., generally <6 months with no lengthy migration-like movements documented.



Movements of eagles classified as (a) long-distance migrants (n = 16) and (b) regional residents (n = 10). Within panels, different colors represent individual eagles. In (a), greenish tracks are eagles outfitted within the Pacific Coast corridor (OR, WA), reddish tracks are eagles outfitted in the Intermountain corridor (NV), and bluish/purplish tracks are eagles outfitted in the Rocky Mountain corridor (WY, NM). Note broad-scale autumn convergence of northern migrants along southern Rocky Mountains and on winter ranges (black circle) on the prairies and deserts of New Mexico, western Texas, and northern Sonora/Chihuahua. In panel (b), stars are eagles outfitted in the Pacific Coast corridor, circles are eagles outfitted in the Intermountain corridor, and squares are eagles outfitted in the Rocky Mountain corridor.

SUMMARY OF KEY FINDINGS

1) Intermountain migration counts reflect primarily a regional-resident population signal; Rocky Mountain and northern Pacific Coast counts primarily northern-migrant population signals. Further refinement may be achieved by temporal partitioning of count data, with long-distance migrants passing mostly during latter half of autumn season.
2) Northern migrants primarily follow the Rocky Mountain corridor, with use of coastal and trans-Great Basin route likely a sign of inexperience.
3) Probability of detecting seasonal movements at migration monitoring sites highest during autumn.
4) Immature eagles occupy restricted winter ranges but wander extensively in summer.
5) Northward shifts in winter range with age likely reflect balancing of migration and winter-survival costs.
6) Migration-route and range fidelity highly variable among young eagles; likely increases with age.
7) Arid/semi-arid plains and deserts of southern and eastern New Mexico, western Texas, and northern Sonora/Chihuahua, Mexico an important winter concentration area for northern migrants, especially younger eagles.
8) Starvation/disease/accidents common causes of mortality among younger eagles; other human-related factors such as poisoning and electrocution more common among older eagles.\
9) Results included documentation of the longest one-way migration (6500 km) ever recorded for a Golden Eagle.

ROUTE AND RANGE FIDELITY

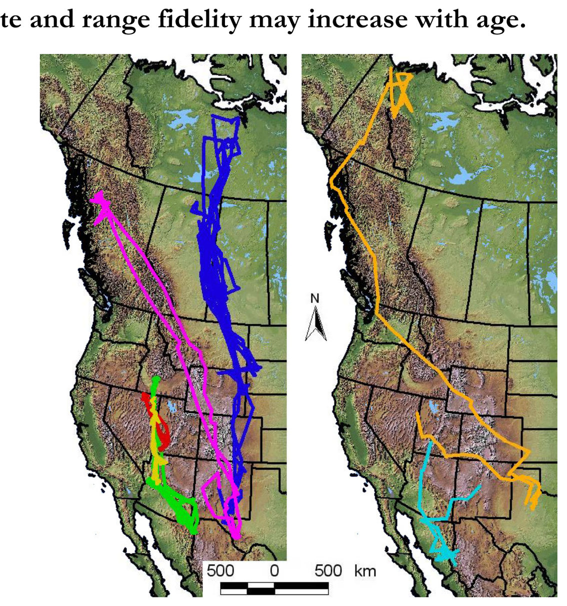
High variability among young eagles

Seven (58%) of 12 relevant eagles showed high spring vs. autumn route fidelity through 1+ annual cycle, with 3 eagles showing high interannual route fidelity (left panel below). In other cases, routes converged across only small portions of the eagles' overall migratory ranges, typically near wintering sites (right panel below). Three eagles showed coarser-scale between-season fidelity; i.e., similar corridor but distinct localized divergences or substantial longitudinal shifts between seasons.

Tracking of 6 eagles through 2+ summer seasons and 9 eagles through 2+ winter seasons revealed no consistent tendencies concerning winter/summer range fidelity (see table to right).

Adult male (a short-distance migrant) showed route and range fidelity across 2 years.

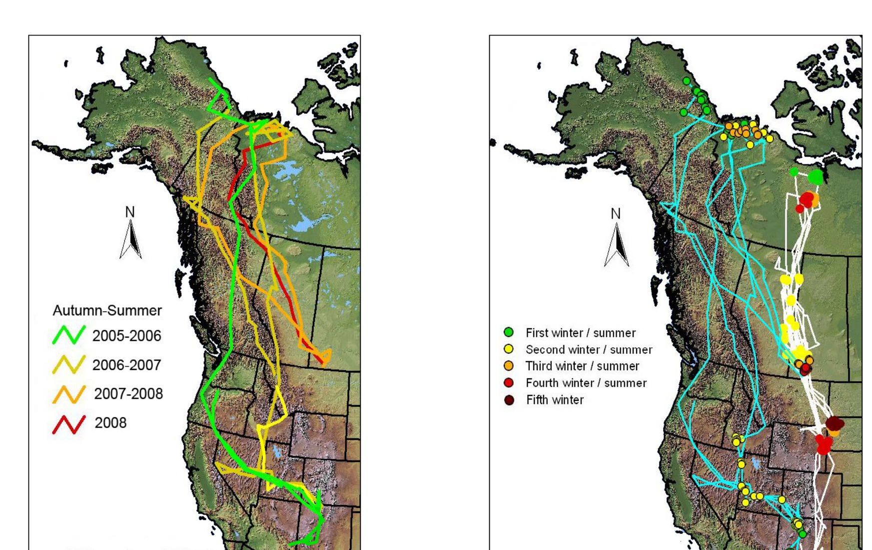
- **Suggests route and range fidelity may increase with age.**



Route and range shifts with age

Northern migrants from Alaska and Canada funnel southward primarily along the Rocky Mountains to access winter ranges on the western Plains and arid prairies and deserts of New Mexico, western Texas, and northern Sonora/Chihuahua, Mexico.

- **Tracking suggested that following a coastal then trans-Great Basin route to reach the NM, TX, n Mexico wintering area may reflect inexperience (see left panel below).**
- **Some young eagles also showed a distinct northward shift in use of winter ranges with advancing age (see right panel below).**



WINTER/SUMMER RANGE CHARACTERISTICS

Young eagles sedentary in winter, wander during summer

Most (82%) relevant eagles occupied restricted winter ranges and only 9% wandered over non-restricted winter ranges.

Only 42% of relevant eagles occupied restricted summer ranges and 42% occupied non-restricted summer ranges.

	Restricted range? Summer (n = 19)	Restricted range? Winter (n = 31)	Range fidelity? Summer (n = 6)	Range fidelity? Winter (n = 9)
No	42	9	50	44
Marginal	16	9	17	11
Yes	42	82	33	44

Both adult eagles occupied restricted winter and summer ranges.

- **Suggests summer wandering is a characteristic of immature eagles.**

Overall geographic range extensive but common habitat themes

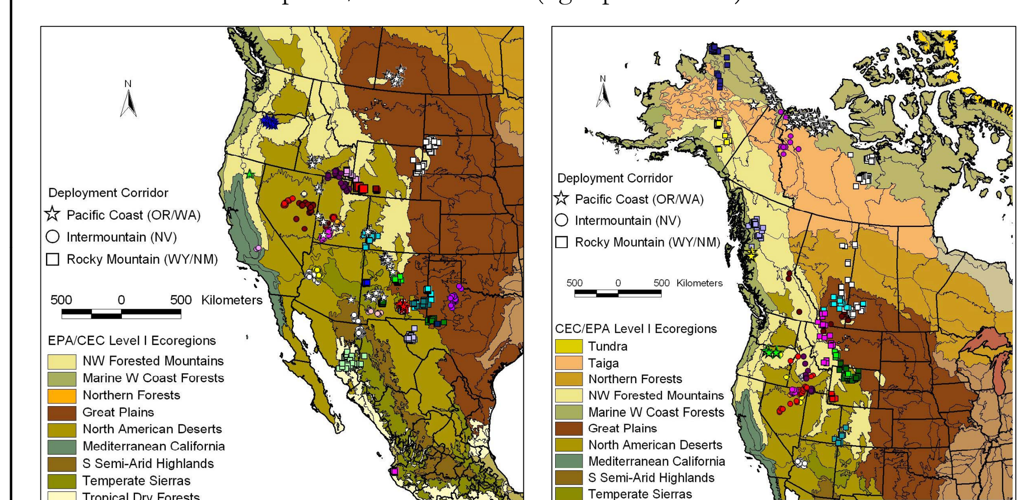
Distribution of winter ranges spanned >3500 km north to south, from southern Canada to southwestern Mexico, and >1500 km east to west, from western Washington to western South Dakota and Texas.

Common habitat theme apparent, emphasizing arid and semi-arid prairies, shrubsteppe, deserts, open highlands, and adjacent montane foothills (left panel below).

- **Among long-distance migrants that summered in Alaska and Canada, one area stood out as a key wintering area, especially for HY/SY birds: the arid/semi-arid plains and deserts of southern and eastern New Mexico, western Texas, and northern Sonora/Chihuahua, Mexico.**

Distribution of summer ranges spanned >5000 km north to south, from the Lisburne Peninsula in northwest Alaska to west-central Arizona, and >1500 km east to west, from northwestern Alaska to central Canada and Wyoming.

Similar habitat theme as in winter, but extending much farther north into boreal/taiga cordilleran and arctic plains/tundra habitats (right panel below).



MIGRATION TIMING VS. MIGRATION MONITORING

Probability of detection higher in autumn than in spring

Broad overlap with typical monitoring periods at long-term sites in western North America, but some cases where full extent of migrations not detectable.

Typical spring monitoring: late February – early May (max late May in Alberta).

Spring migration start dates (n = 17) averaged 13 April ± 29 days (range 16 February – 27 May), end dates averaged 27 May ± 32 days (range 2 March – 28 June), and travel durations averaged 43 ± 29 days (range 5–108 days).

Nine eagles began spring migrations in early May or later; 6 would not have been detected except in Alberta and 2 would not have been detected at any established spring monitoring site.

Typical autumn monitoring: mid-to-late August – early November (max mid-December in CA and Alberta).

Autumn migration start dates (n = 22) averaged 16 September ± 21 days (range 10 August – 31 October), end dates 10 November ± 29 days (range 30 September – 05 February), and travel durations 55 ± 45 days (range 7–166 days).

All autumn migrations began by 1 November and afforded opportunities for detection at latitudes of established monitoring sites.

- **Suggests typical autumn migration monitoring across a broadly distributed network of sites affords a greater chance of detecting most migratory Golden Eagles than typical spring monitoring.**

Only 13% of long-distance migrants were captured before October, whereas this was true for 44% of regional residents.

- **Suggests that temporal partitioning of migration counts may help discern regional-resident versus long-distance-migrant population signals.**

CAUSES OF MORTALITY

Starvation/disease/accidents more common among young eagles; other human-related factors more common among older eagles.

Cause of Mortality	Age at Death[1]: HY	SY	TY	ATY	Total (%)
Starvation/disease [2]	1	5	0	0	6 (46)
Electrocution	0	1	1	1	3 (23)
Poisoning	0	0	1[3]	1[4]	2 (15)
Foraging accident	0	1[5]	0	0	1 (8)
Unknown	0	0	1[6]	0	1 (8)
Total	1	7	3	2	13

[1] HY = hatch year; SY = second year; TY = third year; ATY = after third year.
[2] Carcass intact, not contorted, and no outward signs of trauma or infirmity.
[3] Died splayed out on belly, legs extended backwards, head twisted ~180° and looking skyward, suggesting loss of motor control due to poisoning.
[4] Lead poisoning confirmed by necropsy.
[5] Pinned to side of hill with a large rock on top of its head.
[6] Only a pile of feathers and bones remained 6 weeks after mortality.