

## **MIGRATION PATTERNS OF GOLDEN EAGLE**

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### **Abstract**

*There has been expanding worry for Golden Eagle (*Aquila chrysaetos*) populaces in North America because of current and future projections of mortality hazard and natural surroundings misfortune from anthropogenic sources. Recognizable proof of high-use development halls and bottlenecks for the transitory part of the falcon populace in western North America is a significant initial step to help territory protection and the executives endeavors to lessen the gamble of bird mortality. We utilized unique Brownian Bridge development models to assess usage disseminations of grown-up falcons moving across the western North America and distinguished high-use regions by computing the cross-over of people on populace and provincial levels. On a populace level, the Rocky Mountain Front from east-focal British Columbia to focal Montana and southwestern Yukon enveloped the most involved relocation hallways with our review degree for both spring and fall. Local examination on a 100 x 200 km scale uncovered extra moderate and significant level use halls in the focal British Columbia levels. Birds were more scattered in the spring until their courses joined in southern Alberta. High-use fall halls broadened farther south into focal Wyoming. Information on these high-use regions can support preservation and site wanting to help keep up with and improve transitory Golden Eagle populaces in western North America.*

### **INTRODUCTION**

Protection and the board of raptors requires information on nature and socioeconomics inside the reproducing, wintering, and transitory periods across life stages. For seemingly perpetual raptors

possessing enormous scenes, like the Golden Eagle (*Aquila chrysaetos*), an intensive comprehension of these boundaries across all life stages can be very challenging to accomplish. A rising measure of consideration has been paid to the administration of Golden Eagles in North America because of evident populace declines and in light of the juxtaposition of advancement and assurances managed the cost of by the Migratory Bird Treaty Act (United States and Canada), the Bald and Golden Eagle Protection Act (United States) and the Species at Risk Act (Canada). However ongoing information propose that populaces in the western United States are as of now steady, Golden Eagles actually are considered in danger because of low conceptive likely in blend with territory misfortune and expanding dangers of direct casualty.

The development of modern scale wind power age across North America, which can prompt direct fatalities of Golden Eagles, features the need to recognize significant bird use regions. Numerous regions appropriate for wind improvement cross-over Golden Eagle natural surroundings, yet how much those potential advancement regions cross-over relocation courses stays obscure for most districts in western North America. Also, expansions in other turn of events, for example, oil and gas extraction or sun based energy reap, can prompt environment fracture and increment direct mortality risk through the expansion of electrical cables and streets.

Most investigations of Golden Eagle environment and space use have zeroed in exclusively on the reproducing season in the western United States. Data from winter and during movement is more restricted yet additionally significant for Golden Eagle protection because of contrasts in natural surroundings determination and mortality. Planning high-utilize Golden Eagle relocation halls is a vital stage to assist with distinguishing locales of potential protection significance.

There are a few ordinary strategies to gauge creature space use from GPS got area information from checked people, most remarkably piece thickness assessors. For Golden Eagles, bit assessors have been utilized to characterize the general recurrence of event of an individual or populace in reality (i.e., use circulations). In any case, part determined use circulations don't

represent the worldly construction of creature area information and perform inadequately for effectively relocating creatures.

Both Brownian span and ensuing unique Brownian span, development models (dBBMM) have been utilized to plan and focus on relocation pathways. These strategies benefit from less suppositions than prescient models of developments/determination since courses are for the most part restricted in geographic extension and utilized by numerous people inside the populace. To gauge use conveyances for people that are effectively relocating, the dBBMM develops past strategies by consolidating the distance and time between progressive areas, area mistake, and a unique Brownian movement difference boundary in view of a creature's speed and heading, considering a more precise portrayal and partition of coordinated developments.

Sawyer et al. first used Brownian span models to portray relocation courses and populace level movement hallways for donkey deer (*Odocoileus hemionus*). For avian transients, Brownian span models have been utilized to portray relocation of geese across Asia to assist with illuminating sickness transmission courses and Osprey (*Pandion haliaetus*) movement passageways across the United States. Palm et al. utilized dBBMMs to plan waterfowl relocation flyways in Asia. Mojica et al. involved dBBMMs to make a populace level usage conveyance for Bald Eagles in the eastern United States as an apparatus for assessing wind energy improvement and other likely risks to hawks.

Here, our objective was to distinguish movement passageways of grown-up Golden Eagles at the mainland scale in western North America utilizing dBBMMs. We likewise looked to make a technique by which we could survey local scale relocation pathways utilizing a quantitative methodology in light of test size inside our review degree. Our goal was to keep away from predispositions related with shifting example sizes across the review region and different hawk catch areas/seasons. The reason for this study was to feature high-use halls and bottlenecks as an initial step to illuminating administration and arranging choices as they connect with transitory Golden Eagles in the western United States and Canada.

## **Materials and strategies**

Grown-up Golden Eagles were caught inside six review regions as a feature of various however simultaneous examinations. We caught 16 over-wintering birds inside the "MPG Ranch concentrate on region," which happens inside the Bitterroot Valley close to Florence, MT. We labeled 16 effectively relocating falcons at the "Nora Ridge" concentrate on location during September and October on the Continental Divide of the Rocky Mountains close to Lincoln, Montana. 26 hawks were labeled in the "The Frozen North" concentrate on region while they were on toward the north (i.e., spring) movement through southcentral Alaska. At long last, we caught five overwintering birds across the Great Plains in Montana ("Eastern MT" concentrate on region). Extra information from two falcons were given by the USFWS from the "4-Corners study" being directed in the southwest US, and information from one hawk labeled in southeastern Wyoming were given by the "FWS-Region 6 review." Eagles from MPG Ranch, Eastern MT, Alaska, and 4-Corners were caught utilizing net launchers (Trapping Innovations, LLC, Jackson, WY or Coda Enterprises, Mesa, AZ) goaded with flesh. Hawks from the Nora Ridge study were caught utilizing bow-nets with Rock Doves (*Columbia livia*) as snare. One falcon from the 4-Corners study was struck by a vehicle, restored, and delivered with a transmitter, and the bird for the FWS-Region 6 review was caught utilizing a flesh bedeviled leg-hold trap. Strategies utilized in this study were supported by Montana's and Alaska's Animal Care and Use Committees and adjust to the Guidelines to the Use of Wild Birds in Research.

All falcons were fitted with either 45g or 70g sunlight based Argos GPS transmitters (Microwave Telemetry, Inc, Columbia, MD) utilizing a cross-chest bridle of Teflon strip. Age was resolved in light of plumage. Transmitters were customized to accumulate 10-15 everyday GPS areas during light hours. All information were ordered, organized, and handled through Movebank ([www.movebank.org](http://www.movebank.org)) and downloaded for investigation.

We inspected information from every one of the 64 birds, which included 53 spring and 54 fall movement courses from 2011-2016. We outwardly examined for and eliminated every

undeniable exception (e.g., > 200km development in one hour in an irregular heading from the coordinated development) and any copy records utilizing ArcGIS 10.5 (ESRI, Redlands, CA). We characterized transient developments as coordinated, nonstop developments north or south >100km and removed the principal full fall and spring movement for all people. We eliminated any relocations that showed missing information for >48 h because of deficient sun powered charging.

We just included one occasional movement course for every person to kill pseudoreplication. All movement courses were from grown-up Golden Eagles (> 5-years of age at the hour of relocation). A few people were caught as sub-grown-ups, however we just utilized information gathered after the bird arrived at rearing age. We didn't separate among birds of various reproducing status in light of the fact that most people were not outwardly affirmed as settling. Subsequent to applying these rules to the information, we included 44 spring and 40 fall movement courses in the examinations. 32 hawks contributed information to both spring and fall, while 20 extra birds gave information to one season.

We changed the area information into Alber's equivalent region projection for all investigations. We utilized the MOVE bundle in Program R to compute dynamic dBBMM usage dispersion for every individual relocation course. We set the dBBMM boundaries to the default edge of 13 and window size default of 31, with an area blunder of 150 m and a raster cell size of 2.5km. We outwardly surveyed the attack of the default values to guarantee they caught ca. one day of falcon development and the variety in the information. We utilized almost 100% use circulation shapes for each bird/season and renamed each with the goal that 1 = utilized and 0 = unused surfaces.

We added all renamed usage conveyances via season to make populace level UD's for spring and fall. Mojica et al. made a populace level usage dispersion for Bald Eagles involving a mean incentive for every cell, except this expects equivalent likelihood of purpose by falcons across the whole spatial degree. We caught falcons at different areas during various seasons across our

review region, so we were unable to make this presumption with our dataset. Accordingly, we made four provincial level populace use conveyances for both spring and fall: 25 x 50, 50 x 100, 100 x 200, and 200 x 400 km scales (north/south x east/west). We utilized central measurements to work out the most extreme number of people inside every window size and partitioned the added UD for each 2.5 km<sup>2</sup> cell by that aggregate.

Sawyer et al. utilized an edge of 10% example cross-over as a natural measurement to focus on movement courses of ungulates. They further characterized populace level halls as low, moderate-low, moderate-high, and high use by binning the covering use conveyances in 25% quartiles. We embraced these measure to characterize the spatial degree of our examination and ends as the areas wherein > ca. 10% of our example usage conveyances cross-over (n = 4 people each season). We disposed of regions with <10% of the example usage conveyances covering, which then, at that point, characterized our spatial degree. Inside this degree, we imagined regions inside the territorial relocation passageways as moderate-use and high-utilize based where 50-75% and > 75% of the example covered inside the moving window. Killing the utilization regions in which < half of the example covered gave a modest approximation of purpose hallways.

### **Development**

The Golden Eagle is profoundly portable all through all phases of life subsequent to fledging. Virtually all development is by means of flight, however people are equipped for strolling shockingly significant distances. Flight depends on warm or orographic updraft, with fluttering kept away from with the exception of when important. Telemetry studies give the majority of the data on the developments of people, albeit shockingly huge quantities of birds are counted at some relocation count locales. A large part of the information about development conduct comes from North America and Europe, and similarly less is had some significant awareness of developments of birds in Africa and Asia.

### **DISPERSAL AND SITE FIDELITY**

### **Natal Dispersal and Philopatry**

Introductory developments from a settling site are emphatically impacted by the transient inclination of the populace from which it starts. Thusly, we examine independently transient and non-transitory birds.

### **Dispersal in Migratory Populations**

Post-freedom developments of transient people from inside Alaska incorporate short to significant distance relocations that range an expansive district of western North America. A comparable report in Norway of 25 little birds from a to some extent transitory populace recorded post-fledging developments of 10-1,500 km from the home, with a middle date of flight of 21 October. Direct examination of these two investigations is troublesome on account of the to some degree transient attributes of the Norwegian populace. Large numbers of the hawks named "dispersers" in that study went south and got back to their natal region the accompanying spring.

### **Dispersal in Non-transitory Populations**

Post-freedom developments at calm scopes include nonlinear meandering past the natal region that occasionally follows geography. First-year birds joined (ringed) in Snake River Canyon, Idaho, scattered from natal regions in essentially all headings. Most people experienced didn't move past the limits of nearby states. As a matter of fact, 78% of band experiences were < 100 km, and just 1% of band experiences were > 1,000 km from banding areas.

Each of the 66 Golden Eagles telemetered as little birds in the Colorado Plateau and southern Rocky Mountains left their natal domain in something like one year of fledging. Most (67%) moved < 120 km from their natal home in the first and second year of life. Another 17% moved moderate distances (120-500 km), and 13% moved significant distances (> 500 km). Two birds didn't handily fit in the above arrangement plot, as they consistently left and got back to their bring forth site. As a general rule, really long voyagers were from additional parched regions and had lower endurance rates than did hawks that moved brief distances. Falcons that moved



generally brief distances (< 350 km) went in evidently irregular headings. Nonetheless, birds that moved longer distances would in general travel south, southeast, or east, to regions in northern Mexico or, in one case, Arkansas.

### **Natal Philopatry**

Natal philopatry has been seldom recorded. Radio-telemetry and banding information from non-transitory hawks in Scotland propose that as falcons arrive at rearing age, they will more often than not get back to natal regions. Eight Golden Eagles united in the Snake River Canyon settled a 1 12 area widths from their natal domains. Five of those birds whose character could be affirmed reared 7 to 65 km from their natal homes.

There is some proof that male might be bound to settle close to their natal regions than are females. Six of seven falcons set apart as little birds in Snake River Canyon and later experienced there as raisers were distinguished as guys. The female who got back to settle in the Snake River Canyon moved 44 km, farther than the typical distance moved by guys (32 km), yet not exactly the most extreme distance moved by a male (65 km). Two guys grouped in Utah reproduced 48 and 93 km from their natal homes (American Eagle Research Institute, unpublished information). A female grouped in southwestern Montana previously settled 61 km from its natal home (R. Crandall, unpublished information), and three females joined in the Colorado Plateau-Southern Rocky Mountain area of the southwestern United States reared 19, 66, and 124 km from their natal homes. Conversely, a hereditary report in Scotland proposed that significant distance dispersal was male-one-sided.

### **Grown-up Fidelity to Breeding Site and Dispersal**

Grown-up birds frequently show constancy to reproducing destinations. Most telemetered grown-ups more than once utilize the equivalent settling an area for the whole time their telemetry unit capacities (TEK, CLM, TAM), yet labeled birds sometimes switch regions (G. Chase, individual correspondence). One checked individual stayed on the equivalent settling an



area for  $\geq 12$  years in Idaho (Snake River Canyon, USGS, unpublished information). Firmly related Imperial Eagle and Spanish Eagle are comparatively devoted to settling domains, with for the most part low paces of an area exchanging. White-followed Eagle, which is all the more indirectly related and has different biology, seems to switch settling domains all the more as often as possible.

There are not many records of birds moving starting with one settling an area then onto the next (i.e., rearing dispersal). This conduct might be undervalued and the justification for these developments are not surely known. A radio-followed female utilized settling domains 15 km separated in sequential years in Snake River Canyon (USGS, unpublished information). Three individual region holders (one female, two guys) followed by radio telemetry exchanged domains in California. These birds got comfortable various domains inside 8 km of their old ones, by and large 10 days to 90 days subsequent to leaving their unique regions. Natural surroundings change close to the first settling site might have encouraged one of these moves (G. Chase, individual correspondence).

### **Relocation Overview**

Populaces might be non-transient, to some extent transitory, or short-medium-or significant distance transitory. Island populaces (e.g., the United Kingdom) are by and large non-transitory, and birds will generally remain on or close to regions all year. Birds from non-transitory central area mainland populaces might make longer-distance developments from regions more often than do their island partners. Transients might cover brief distances (e.g., inside Scandinavia) or very significant distances (e.g., from northern Alaska and Canada to southern United States and Mexico), and may go in a north-south or south-north heading in one or the other season.

People from northern reproducing regions are typically transient, and northern domain holders will quite often relocate longer distances than people settling farther south. Northern falcons can move south  $> 5,000$  km from rearing to wintering regions. In eastern Canada, essentially all people are transitory (TAM, TEK). In western North America, apparently people that home

south of 55°N frequently are not transient, and those north of there frequently are transitory (the creators). In Scandinavia and Alaska, populaces are somewhat or entirely transitory, possible in light of prey accessibility. For instance, a few birds from Alaska might overwinter in inside and northern pieces of the state when snowshoe rabbit (*Lepus americanus*) are plentiful. People from south-focal Alaska (T. Blasts, unpublished information), western Alaska (CLM) and the Gaspé Peninsula of Quebec might remain nearby northern rearing reaches a few years and move south during different years.

Relocation examples of falcons in bone-dry region of the southwestern North America seem not the same as those farther north. In these populaces, pre-grown-ups travel through New Mexico and western Texas toward the start and end of winter. Following information propose that toward the north developments of these birds might be thought of as transitory. Distributed telemetry studies recommend broad cross-over in western North America between people from transitory and non-transient populaces. There is no data concerning whether hawks from bone-dry areas of southern Europe and the Middle East participate in comparative ways of behaving.

### **Migratory Courses**

Major transitory courses of North American Golden Eagles happen along the Pacific Coast Ranges, the Rocky Mountains, the Appalachian Mountains, and through the Great Lakes district. Insights regarding these relocations change via season. This occasional variety being used of courses is logical driven by comparing variety in accessibility of updrafts that work with flight and in the inspiration for movement. For instance, in the Appalachians, thermals become more accessible as spring advances grown-ups are headed to get back to settling grounds sooner than are subadults.

Relocation courses across the inside and south-focal areas of Alaska and the southern piece of the Yukon, Canada, will generally run east-west and northwest-southeast. Notwithstanding, beginning in northern British Columbia, relocation courses are dominantly north-south to northern Mexico. Pre-winter and spring relocation hallways in the northwestern piece of North

America in Alaska, Yukon and Northwest Territories for the most part will generally be wide. For instance, the movement hall traverses around 400 miles across the southern Yukon, northern British Columbia, and northwestern Alberta. At 55°N scope, the movement passage ranges ~300 miles from focal British Columbia toward the eastern slants of the Rocky Mountains in Alberta. The passage becomes more extensive again 49°N scope at the boundary of Canada and the coterminous United States.

There is likewise great proof of a movement hall along the shoreline of southeastern Alaska and western British Columbia (NPS, USFWS, USGS, unpublished information; TEK, TAM, EHC). Quantities of hawks relocating through this area are presumably undeniably not exactly those moving inland toward the east of the Coast Mountains (CLM).

Information from telemetry and long stretches of visual perceptions plainly show that enormous quantities of relocating falcons gather at explicit locales. In Alaska and Canada, these locales remember the Matanuska-Susitna Valley and Gunsight Mountain for south-focal Alaska; B. Dittrick and T. Swem, individual correspondence); the Mentasta Mountains in eastern inside Alaska; the Shakwak and Tintina Trenches, Kluane Lake and Ruby Range locales in southern Yukon, Canada (Sinclair et al. 2013); the northern Rocky Mountains remembering the Cassiar Mountains for northern British Columbia; and the northern Rocky Mountains and Canadian Rocky Mountains in western Alberta, including Mt. Lorrette in the southern piece of the Canadian Rocky Mountains in Alberta (Rocky Mountain Eagle Foundation, unpublished information). There are likewise various fixation regions in the coextensive United States.

Telemetry studies have given nitty gritty data on pre-winter relocation courses in eastern North America. Grown-ups settling in Quebec and Labrador regularly move south, concentrating along the north shore of the Gulf of St. Lawrence and along the edges of the Appalachian Mountains. A few people, particularly more youthful birds, drop down the Atlantic coast. Brilliant Eagles from western Quebec relocate through the Great Lakes district, passing by the Mackinac Straits, Michigan, through the Michigan Upper Peninsula into Wisconsin or along the north shore of

Lake Erie. People from Ontario and Manitoba ordinarily move south toward the north shore of Lake Superior and pass by Hawk Ridge, Duluth, Minnesota, yet some pass through the Mackinac Straits as do birds settling farther east. Relocation through the Midwest south of the Great Lakes is normally scattered however seems to follow forested and riparian halls (TAM).

Spring movement halls in the eastern United States happen principally along the edges of the Appalachian and Allegheny Mountains, particularly from the get-go in the season. The passageway augments as spring advances because of higher warm movement that advances taking off away from ridgelines. Routinely recorded at relocation include destinations in Pennsylvania, western Maryland, Virginia, West Virginia, North Carolina, Tennessee, and along the shores of Lake Ontario in New York. Spring relocation likewise happens in the Great Lakes district. At Whitefish Point, Michigan, expanding numbers were noticed for a long time after 1986. The most noteworthy spring includes in eastern North America happen at the Mackinac Straits in Michigan and at Tussey Mountain in focal Pennsylvania. Brilliant Eagles are uncommon at seaside movement count destinations (i.e., Sandy Hook, New Jersey; Cape Henlopen, Delaware; Plum Island, Massachusetts) and at relocation include locales in Massachusetts, Vermont, and Maine .

### **Migratory Connectivity**

Transitory network geologically interfaces people and populaces among life cycle stages (300). At the point when transient network areas of strength for is, stay near one another in all times of the year (i.e., people that late spring in a similar region likewise winter together). At the point when network is feeble, people that are together in one season are not together in different seasons (i.e., people that mid year in a similar region don't winter together, or, on the other hand, falcons that colder time of year in a similar region don't summer together).

There have been no proper appraisals of the strength of transient availability of North American or Eurasian populaces. In any case, it is feasible to draw some deduction about transitory availability from writing portraying Golden Eagle relocation. 28 hawks brought forth and

telemetered in Denali National Park and Preserve, Alaska, wintered at scopes from focal Alberta to New Mexico. In any case, of those birds followed into the next year, all summered north of the Brooks Range, Alaska. 52 Golden Eagles caught at wintering areas crossing the Appalachian Mountains from New York to Alabama summered in environments that covered the northern 66% of Quebec and a lot of Labrador. These patterns recommend low degrees of transient availability of Golden Eagles inside every one of these districts. Nonetheless, when considered at a mainland scale, there give off an impression of being moderate degrees of network (252). For instance, Golden Eagles that late spring in northeastern Canada additionally enjoy the colder time of year with different falcons from the district in the eastern United States and don't seem to connect with birds that late spring in Alaska and northwestern Canada. Besides, birds from focal Canada (Manitoba, Ontario) will generally winter farther west than do hawks that late spring in northeastern Canada (TAM, unpublished information).

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