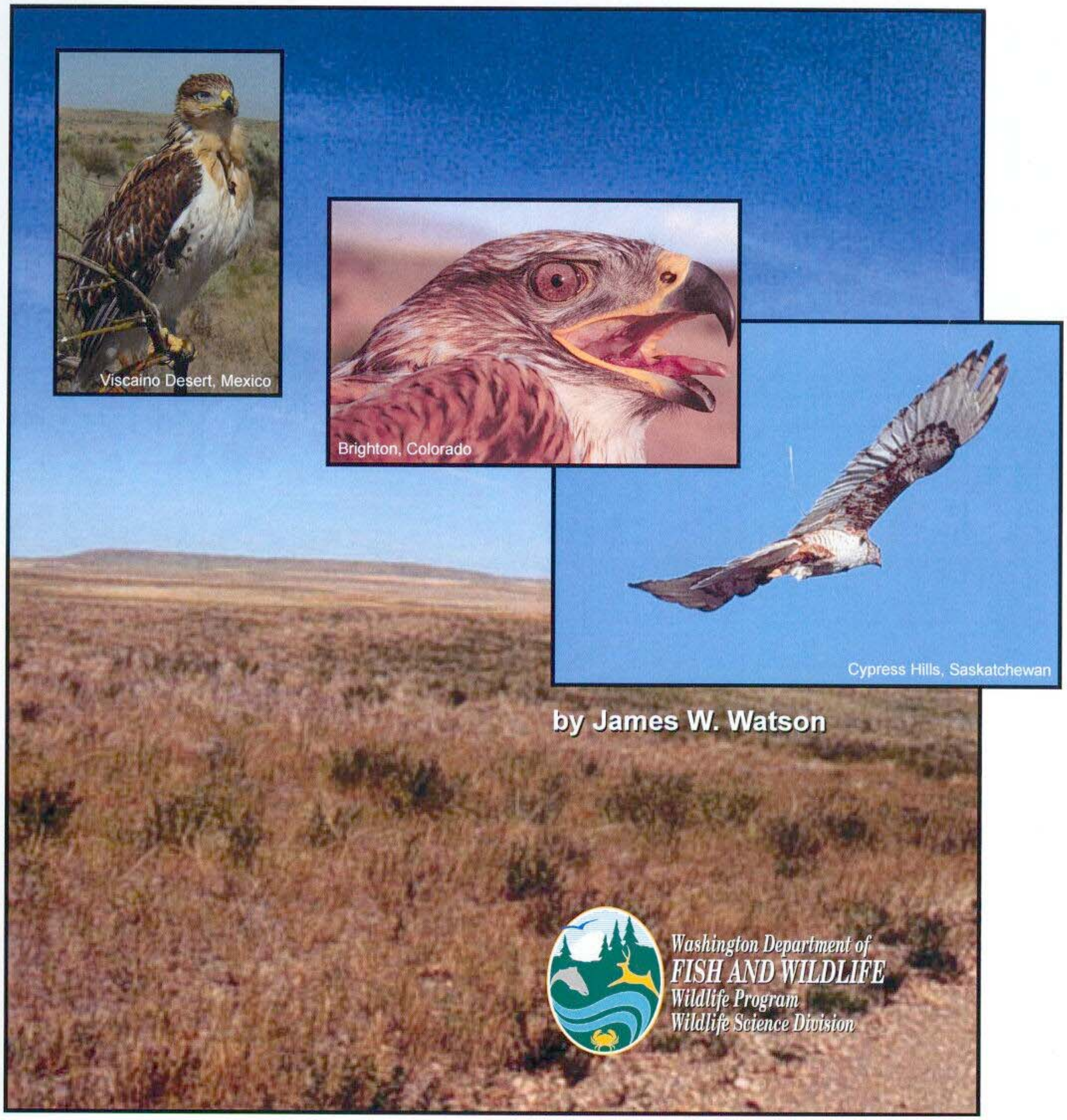
STATE OF WASHINGTON October 2003

Migration and Winter Ranges of Ferruginous Hawks From Washington



Viscaino Desert, Mexico

Brighton, Colorado

Cypress Hills, Saskatchewan

by James W. Watson

Washington Department of FISH AND WILDLIFE
Wildlife Program
Wildlife Science Division

WDFW 667

Final Report

MIGRATION AND WINTER RANGES OF FERRUGINOUS HAWKS FROM WASHINGTON

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Final Report
October 2003

Cover photos by Bob Davies, Jerry Liguori, and Jim Watson

Suggested Citation:
Watson, J. W. 2003. Migration and winter ranges of ferruginous hawks from Washington. Final Report. Washington Department of Fish and Wildlife, Olympia, Washington, USA.

EXECUTIVE SUMMARY

Between 1999 and 2003, 13 adult and 15 juvenile ferruginous hawks (*Buteo regalis*) from Washington were monitored via satellite telemetry to assess their migration, range use, and survival. These factors were studied to better understand ferruginous hawk ecology and population dynamics, and to promote recovery of this species from state Threatened status. Adult hawks migrated twice. Post-nesting migration of 10 hawks was longitudinal to the eastern front of the Rocky Mountains in Alberta and Montana, and was a functional response to populations of Richardson's ground squirrels (*Spermophilus richardsoni*). Post-nesting migration of 3 adult hawks was to the Great Basin. In the fall, hawks migrated latitudinally to winter ranges. Eight hawks wintered in central California and fed on California ground squirrels (*S. Beecheyi*), 2 hawks wintered in the Central Plains, and 1 bird returned to his territory in Washington. The Continental Divide was not a physical barrier to hawk migration, and the population exhibited broad-fronted migration without using specific flight corridors. Adult males migrated through or remained on territories in route to winter ranges, whereas most females migrated through the Central Plains. Sexual differences in migratory patterns may have resulted from differences in prey preference and territory affinity. Six adults monitored for 2 seasons exhibited markedly similar migration patterns, and high winter range philopatry. There was a 100% return rate of adults to breeding territories in spite of drought conditions and declining productivity in this localized area of the nesting range. Cumulative adult survival over 4 years was 0.46 (±0.15), and no consistent cause of mortality was identified for adult hawks.

Juvenile hawk migration was characterized by high initial mortality and exceptional movements. At least 3 of 8 juveniles died from starvation, and cumulative juvenile survival was 0.43 (±0.10) at 1 year. Juveniles wandered extensively for an average of 6,139 km throughout western North America during 90 days prior to their settling on winter ranges in California, the Central Plains, and Mexico. Young and adults from the same nests migrated independently and followed dissimilar migration patterns. Two young migrated over 2000 kilometers less to winter ranges in their second year, compared to the first year. These factors suggested there was a strong learning component to the establishment of individual adult migration routes.

A lack of nomadism, high adult fidelity to breeding sites, and movement of immature birds back to the Pacific Northwest during the nesting season indicate the population of ferruginous hawks in Washington is self-sustained. The population is maintained by hawks that range widely during 49% of the year when they are exposed to multiple mortality sources. Direct mortality of adults in winter may be less of an issue to survival rates than indirect effects of habitat loss. Maintenance of prey and habitat resources, principally in the Northern Plains and central valley of California, are important to sustain hawks through the winter and replenish adult fat reserves for reproduction the following spring. Widespread agricultural conversion and urbanization are real and significant threats to these habitats. Juvenile survival, although less important than adult survival to population maintenance, is most impacted by poor foraging conditions in Washington, likely a result of depressed prey populations and drought. Protection of this population, and other migratory ferruginous hawk populations, will require regional and international cooperation.

TABLE OF CONTENTS

EXECUTIVE SUMMARY. iii

LIST OF TABLES. v

LIST OF FIGURES. vi

INTRODUCTION. 1

STUDY AREA AND METHODS. 2
- Trapping and Telemetry. 2
- Mortality Factors and Survival. 4
- Movement and Range Analysis. 5

RESULTS. 6
- Trapping Summary and PTT Status. 6
- Mortality Factors and Survival. 6
- Adult Migration. 9
  - *Overview*. 9
  - *Summer Migration and Fall Ranges*. 9
  - *Fall Migration and Winter Ranges*. 16
  - *Spring Migration and Breeding Ranges* 18
- Juvenile Migration. 18
- Summer Migration and Fall Ranges. 18
- Spring Migration and Breeding Period Movements. 20

DISCUSSION. 20

MANAGEMENT IMPLICATIONS. 26

ACKNOWLEDGEMENTS. 27

LITERATURE CITED. 28

APPENDICES 34

LIST OF TABLES

Table 1. Fate and survival time of telemetered ferruginous hawks captured in southcentral Washington, 1999–2002 as of September, 2003. Fate was determined from last observation, PTT location and PTT activity information. Post-capture survival time was determined from PTT activity information and from observations of telemetered or banded hawks after PTTs expired. Survival time is minimum for hawks known to be alive at last observation and those with unknown fates. 7

Table 2. Timing and patterns of movement of adult ferruginous hawks from and to breeding territories in south-central Washington 1999–2003. Locations where hawks became localized for 5 days are indicated. For hawks that returned to territories in the spring the last location identified is the wintering area. 11

Table 3. Migration statistics of 13 adult and 11 juvenile ferruginous hawks from south-central Washington, 1999–2003 (± SD). 13

Table 4. Occupancy (days on range, ± SD) and size (km^2, ± SD) of seasonal ranges used by 13 adult ferruginous hawks from Washington. Ranges were 100% minimum convex polygons estimated from class 1–3 satellite locations. 13

Table 5. Timing and movement patterns of juvenile ferruginous hawks from natal territories in southcentral Washington, 1999–2003. Locations where hawks remained for 5 days are indicated. Date of the beginning breeding season during the second year was determined on the date after hatch-year birds migrated from winter ranges, and ended when they migrated to winter ranges. The last location for each fall/winter season is the wintering area for hawks that are not identified as mortalities. 19

LIST OF FIGURES

Fig. 1. Ferruginous hawk study area in south-central Washington where adults and fledglings were telemetered and monitored from 1999–2002. 3

Fig. 2. Kaplan-Maier survival estimates (±95% CI) of telemetered adult (top) and juvenile ferruginous hawks (bottom) in Washington, 1999–2003. Hawks were captured in June. 8

Fig. 3. Locations where telemetered juvenile and adult ferruginous hawks died between 1999 and 2003. 10

Fig. 4. (Top) Migration patterns of 13 adult ferruginous hawks from southcentral Washington. For hawks monitored 2 years, only the first migration is shown. (Bottom) Complete migration of 4 adult male ferruginous hawks in 2 successive years depicted by solid and dashed lines. 12

Fig. 5. Ranges used by adult, juvenile, and after hatch-year ferruginous hawks telemetered in Washington. Breeding season ranges were occupied from March to mid-July, fall ranges from mid- July to August, and winter ranges from September to February. Parentheses indicate number of satellite locations. 15

Fig. 6. Time budgets of adult ferruginous hawks from Washington state on fall ranges (*n* = 1,195 hawk-days) and winter ranges (*n* = 1,316 hawk-days) in western North America. NP = Northern Plains, RM = Rocky Mountains, GB = Great Basin, CL = Columbia Plateau, CP = Central Plains, and CT = California Trough. 16

Fig. 7. Locations at which adult (yellow lines) and juvenile (white lines) ferruginous hawks crossed the Continental Divide after migration from Washington state. Orange polygons represent fall ranges of adults (100% minimum convex polygons) estimated from class 0–3 satellite locations. 17

Fig. 8. Migration of related adult (solid lines) and juvenile (dashed lines) ferruginous hawks from south-central Washington. (a) Territory 184, adult female 15184 (1999–2000) and juvenile female 15218b (2001). (b) Territory 301, adult female 15185 and juvenile female 10372 (both 1999–2000). (c) Territory 162, adult male 10394, juvenile male 10394 (both 2000–2001). (d) Territory 87, Adult male 15184b and juvenile female 15185c (both 2002–2003). 21

INTRODUCTION

The ferruginous hawk (*Buteo regalis*) is a large raptor that nests in arid, native prairie ecosystems of western North America. Washington state is on the northwestern edge of the species breeding range (Bechard and Schmutz 1995) and historically supported a substantial population of 241 territories (Wildlife Resource Data System [WRDS], Washington Department of Fish and Wildlife [WDFW]). Increasing fragmentation of shrubsteppe habitats from agricultural conversion and residential development has been a factor contributing to the decline and listing of the ferruginous hawk as a state Threatened Species. Associated disappearance of shrubsteppe mammals, such as black-tailed jackrabbits (*Lepus californicus*) and the Washington ground squirrel (*Spermophilus washingtoni*), have contributed to dietary shifts of ferruginous hawks to smaller mammals, insects, and gulls (Larus spp.) (Leary et al. 1996, Richardson et al. 2001). Changes in prey and increased distance to foraging ranges may be affecting population numbers by reducing hawk survival (Leary et al. 1998, Richardson et al. 2001). In 2002, only 20% of the historic ferruginous hawk nesting territories in Washington were occupied, and many of these have remained vacant for years (WRDS).

Ferruginous hawk winter ecology has important implications for the heath and status of the nesting population but is less studied than nesting ecology. The species winters from the southwestern United States into central Mexico (Bechard and Schmutz 1995). In Washington, ferruginous hawks are usually absent from territories between August and March but winter ranges are unknown. Overwinter survival may limit the size of the breeding population (Schmutz 1984, Plumpton and Andersen 1997) so understanding winter habitat, prey characteristics, and mortality factors is important. Nomadism has been hypothesized as one explanation for sporadic breeding (Woffinden and Murphy 1989), underscoring the need to understand migration and range philopatry. Because Washington is on the edge of the breeding range where habitat and prey conditions may not be optimal, winter survival, movements, and philopatry may be particularly important to sustaining the population. It is not known whether the Washington population is a self-sustaining source population, or a sink population that depends on recruitment from other breeding areas.

Observations of wintering ferruginous hawks have provided some information on associations to prey distribution in the central and southern plains (Allison et al. 1995, Plumpton and Andersen 1997), principally black-tailed prairie dogs (*Cynomys ludovicianus*) which were recently considered for listing by the U.S. Fish and Wildlife Service. Extensive banding of juvenile hawks east of the Continental Divide from Saskachewan south to Colorado have shown nearly all of these birds wintered east of the Rocky Mountains throughout the central plains and into Mexico (Lincoln 1936, Salt 1939, Harmata 1981, Gilmer et al. 1985, Schmutz and Fyfe 1987, Houston et al. 1998, Harmata et al. 2001). Banding of ferruginous hawks west of the Continental Divide in Idaho (Thurow et al. 1980) and satellite telemetry of 11 hawks from Idaho and Utah suggested hawks from these areas crossed the continental divide and moved widely throughout the west (Schueck et al. 1998). This study also found 4 individuals returned to the capture location from the previous season. Band recoveries of wintering ferruginous hawks in California also identified origins in Utah, Oregon, and Montana (Garrison 1990). Analysis of all historic band records, and morphological and genetic characteristics of captured individuals, did not find evidence of distinct subpopulations of ferruginous hawks east and west of the Rocky Mountains suggesting a degree of genetic mixing occurs across the Continental Divide (Gossett 1993).

Satellite telemetry is a technology that allows long-range and multi-season monitoring of raptors anywhere in the world (Brodeur et al. 1996, Kjellen et al. 1997, Ueta et al. 1998 Britten et al. 1999). Satellite transmitters, or Platform Transmitter Terminals (PTTs), regularly broadcast raptor locations for several months or years. PTT activity information (i.e., moving or stationary) can be used to assess mortality and provide survival estimates. In spring, 1999, I initiated a study to investigate the migration of adult and juvenile ferruginous hawks from south-central Washington using satellite telemetry. I report here on the results of that investigation, with specific objectives to (1) describe winter mortality factors and survival of adult and juvenile hawks, (2) describe hawk migration characteristics, winter range, and breeding range philopatry, and (3) identify hawk winter ranges and associated prey.

STUDY AREA AND METHODS

Trapping and Telemetry

In May of 1999–2002, ground surveys were conducted in Benton and Franklin Counties of south-central Washington to identify active ferruginous hawk nests. This area was within the core of the breeding population in Washington (WDFW 1996) and included the Hanford National Monument and Juniper Dunes Wilderness (Fig. 1). In these areas of expansive shrubsteppe, hawks nested in transmission towers and Juniper trees (*Juniperus communis*), respectively. Most nests on private land were in native prairie habitats with variable elevation gradients (i.e., coulees or hills) often surrounded by agricultural fields or orchards on adjacent level ground. Nests in these areas were usually on rock outcrops and cliff faces. Details of habitat characteristics, including specific vegetation types are provided elsewhere (Nugent 1995, WDFW 1996, Leary 1996, Jerman 1999).

After locating active nests, the first day of incubation was recorded within 2 days, and nests were rechecked on the estimated hatching day based on a 32-day incubation period (Palmer 1988). Because of the small size of the breeding population, I limited the target sample of adult hawks to 15 individuals. Fifteen fledgling hawks were also targeted for telemetry. Adult hawks were captured using break-away mist nets (Bloom et al. 1992) when young were 7–26 days old. Nets (30-foot, 2 ply, black-colored, set to break-away on 3, 91 cm [36 in] poles) were arranged in a triangle with the lure bird, a live great horned owl (*Bubo virginianus*), tethered at the center. Traps were set at dawn in the nearest level opening <100 m from the nest. A portable blind was erected <50 m from the trap set where a taped great horned owl vocalization was played once every 10 min from a portable hooting device (Wildlife Callers, Bellevue, Washington, USA). If hawks were unresponsive to the owl lure, a bal-chatri baited with 2 gerbils was placed in sight of the nest. Trapping efforts were abandoned if hawks failed to respond after 45 min. Neither gender was specifically targeted for capture and only one adult was captured at each nest. Captured hawks were weighed, banded with USGS tarsal bands, and measured (i.e., weight,

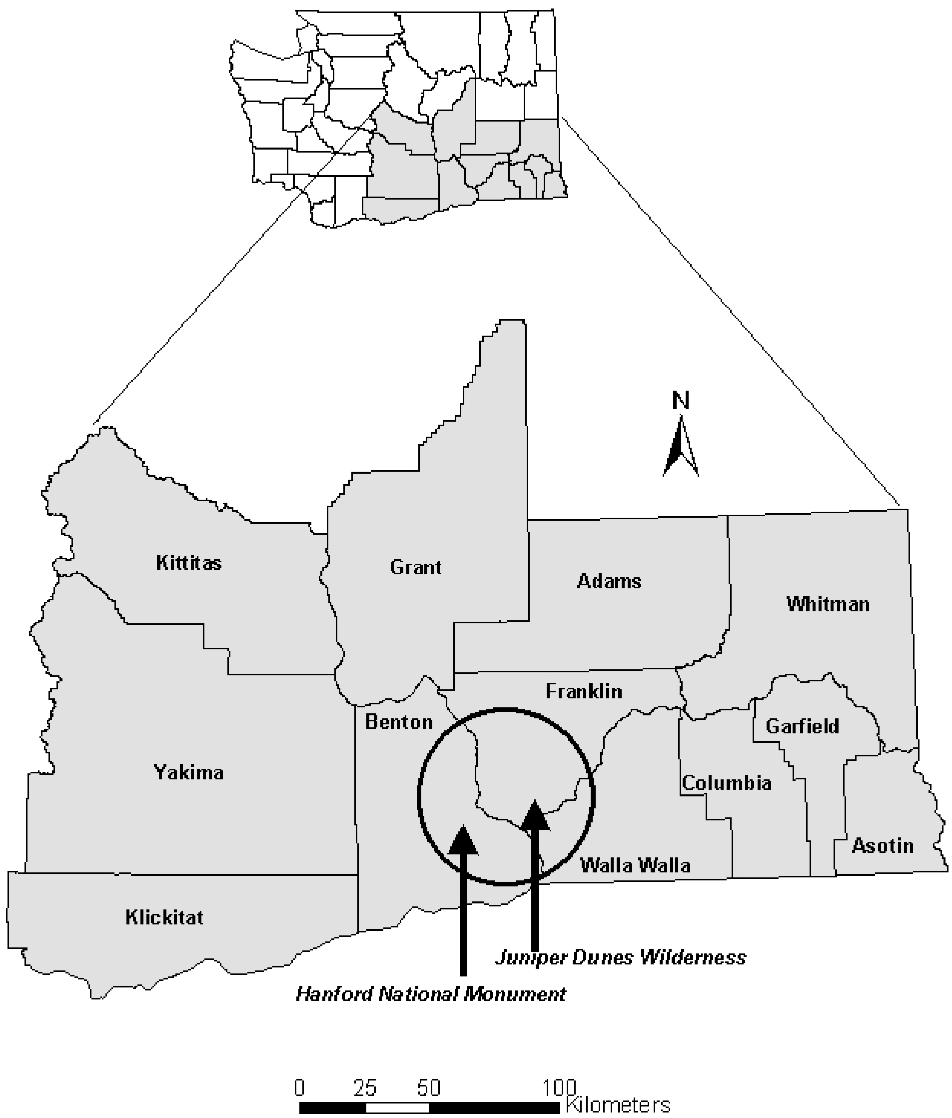

Fig. 1. Ferruginous hawk study area in south-central Washington where adults and fledglings were telemetered and monitored from 1999-2002.

wing chord, hallux length, and beak depth). Gender of hawks was determined from copulatory behavior, differences in nest attentiveness (e.g., females most attentive), food provisioning activity (e.g., males primary foragers), and confirmed by size dimorphism of body measurements (Appendix A, Table 1). Hawks were outfitted with 30-gram PTTs from *Microwave Telemetry, Inc.,* programmed to broadcast every 4 days. PTTs were attached with "X-attachment" backpacks (Buehler et al. 1995) using 7-mm wide teflon ribbon. Hawks were released at capture locations <1 hr following their capture. In 1999, 5-gram VHF transmitters from *Advanced Telemetry Systems, Inc.* were piggy-backed to PTTs for local monitoring of hawks prior to migration. VHF transmitters had an expected life of 60 days and were programmed for 12 hr on/ 12 hr off. The intent was to monitor local hawk movements and foraging behavior in May and June prior to migration. VHF transmitters functioned sporadically and consistent observations were obtained for a few birds, so VHF monitoring was discontinued thereafter. Nestlings were banded at 35 to 40 days old. The oldest young in multiple broods were telemetered just prior to fledging. Juveniles were outfitted with 18-gram solar PTTs that broadcast daily, or 30-gram PTTs programmed to broadcast every 8 days to extend battery life to include multiple seasons.

Satellite locations and PTT sensor information for activity, temperature, and voltage were retrieved daily via computer. Satellite locations were coded by the ARGOS system into one of seven classes (Service Argos, Inc. 1994) based on the quality of the data received: location class 3 accurate <150 m; 2<350 m; 1<1000 m; 0>1000 m (i.e. no more accurate than 1000 m); A (no accuracy); B (no accuracy); Z (invalidated location).

Mortality Factors and Survival

Ground visits were made to the western states and Canadian Provinces in September 1999 and 2000 to obtain information on potential prey and habitat where telemetered hawks became localized (i.e., remained 5 days). Searches were conducted for hawks, sites were photographed, and habitat and potential prey described. Local biologists from federal, state, and provincial governments were contacted to obtain anecdotal information on ferruginous hawk historic abundance and prey use in fall and winter and to assist in ground searches for dead hawks. Hawk mortality was assessed by evaluation of PTT activity and temperature sensor data from satellite readouts, and recovery of carcasses. Activity sensors functioned when PTTs moved; thus, the PTT was stationary if the counter remained the same over several transmissions (e.g., >2 weeks). Temperature readings (recalibrated to actual temperatures from ARGOS coding) provided a further indication that hawks were dead; PTTs on living birds had temperatures between 10°C and 35°C, but typically dropped to below 10°C or above 35°C and mirrored ambient temperatures on dead birds. I assumed no PTTs became detached from hawks during the study duration based on previous experience with the attachment method (Watson and Pierce 2001) and multiple-year testing of the harnesses exposed to weather conditions where sutures remained intact (unpubl. data).

Survival rates of adult and juvenile ferruginous hawks were estimated separately. Because adult hawks were territorial, they were monitored beyond the time their PTTs expired and their survival estimated annually from 1999–2003. Juvenile hawk survival was estimated every 2 months post-capture until PTTs expired (i.e., 2 years). Juvenile raptors experience multiple survival bottlenecks in the first several weeks of life (e.g., fledging, pre-migration, migration, etc.; Todd et al. 2003), potentially reflected in frequent, monthly survival estimates.

The Kaplan-Meier product estimator with a staggered entry design (Pollock et al. 1989) was used to estimate survival of all telemetered hawks. This estimator allows staggered entry of animals into the model (i.e., birds are telemetered at different times) and the censoring of birds with undetermined fates (e.g., birds lost from contact after their PTTs expired or when they disappeared prior to PTT expiration without any indication of mortality). The model assumed a random sampling of sexes, independence of survival times for different birds, and no effects of transmitters on survival (Pollock et al. 1989). There was no evidence that these assumptions were violated.

Movement and Range Analysis

Class 0–3 satellite locations were plotted from every transmission to delineate migratory pathways. Field testing of class 0 locations in northwestern Washington estimated error bias of 1.7 ± 2.2 km for latitude coordinates, and 4.4 ± 4.8 km for longitude coordinates (Watson and Pierce 1998). Thus, class 0–3 locations were considered accurate to <10 km of actual locations. To further refine location quality, outlying locations were excluded when they were beyond the distance (e.g., 500 km) in which hawks could have moved from the time since the previous location (e.g., 1 hour). Such outliers were particularly obvious when the prior and subsequent location were in close proximity (e.g., 5 km). Distances hawks moved among locations in migration were estimated with the Animal Movement extension for ARCVIEW (Hooge and Eichenlaub 1997). Paired t-tests were used to compare total migration distance between the sexes, and the timing of migration between the sexes relative to the fledging date of young.

Class 0–3 locations were plotted to show geographic regions used by hawks in fall and winter. The number of days adult hawks spent in one area (hawk-day) was estimated and pooled among hawks to determine the time budgets for the population among broad geographic regions in fall and winter. Regions included the Northern Plains (southeast Alberta, southwest Saskatchewan, North Dakota, and South Dakota), Rocky Mountains (southwest Alberta from Banff to Cardston, and northwest and southwest Montana), Great Basin (far southeast Idaho, northeast Nevada, and Utah), Columbia Plateau (Washington, Oregon, southwest and southcentral Idaho), Central Plains (Nebraska, Colorado, Oklahoma), and California Trough (central Valley of California). Because locations were not received for each bird every day, I could not always determine the day eagles left a region when birds moved between transmissions. In those instances, the time between locations was divided equally between the 2 regions (e.g., 4 days/2). Location classes A and B were used occasionally to better identify the day on which hawks made major movement shifts. Dates on which hawks began occupation of their fall and winter ranges were determined from the time when hawks remained at a particular location for 5 days. Dates on which hawks moved from ranges were more obvious because movements were usually abrupt.

Class 1–3 locations were used to estimate sizes of fall and winter range sizes (100% minimum convex polygons) with the Animal Movement extension in ARCVIEW (Hooge and Eichenlaub

1997). I plotted ranges for general interpretation of range size and location, but not to identify core areas or intensity of range use that might have been biased by autocorrelated locations. Although satellite locations used for interpretation of ranges had an associated error bias potentially larger than conventional VHF telemetry (i.e., <1 km), effects of that bias were small based on the scale of range use that hawks exhibited. Furthermore, when satellite telemetry locations were widely distributed (e.g., 500 km^2) their utility in estimating range size outweighed the disadvantage of location bias because satellite locations are typically greater in number, more frequently obtained, and acquired in areas that may be inaccessible and more poorly represented by ground tracking (Grubb et al. 1994, Ballard et al. 1998).

RESULTS

Trapping Summary and PTT Status

From 1999–02, 28 ferruginous hawks were telemetered, including 13 adults and 15 juveniles (Appendix A, Tables 2 and 3). Ten other hawks were banded only. Female hawks at 2 territories had been banded previously (May Junction, WDFW occno.184, and WPPSS, WDFW occno.132). The former bird was banded as an adult in 1992 on a territory located 3 km away (i.e., Dune, WDFW occno.199; A. Leary, pers. comm.) and was at least 13 years old in 2003. The latter bird was banded as a juvenile in the vicinity of the Hanford National Monument 11 years earlier (Bird Banding Lab, Laurel MD).

As of 15 July, 2003, 8,387 satellite locations had been received from all PTTs, accounting for 7,931 hawk-days (1 hawk day = 1 hawk monitored for 1 day) (Appendix A, Table 3). PTTs on 3 hawks continued to broadcast at the time analysis was conducted for this report. Adult hawks were monitored for an average of 407 days (SD ± 196) at 484 (SD ± 256) locations. Juvenile hawks were monitored for an average of 176 days (SD ± 219) at 140 (SD ± 163) locations. Differences in monitoring intensity largely reflected the higher mortality rate of juvenile hawks (see below). Class 0–3 locations (n = 3,980) accounted for 48% of all locations and were used for interpretation of migration pathways and ranges.

Mortality Factors and Survival

Six adult hawks and 8 juveniles died during the study (Table 1). Six mortalities (43%) were natural or accidental, 5 hawks (36%) died of unknown causes, and 3 mortalities (21%) were attributed to human causes.

Cumulative survival of adult hawks (±95% CI), estimated from June to June, decreased from 0.76 (±0.11) at 1 year, to 0.46 (±0.15) at 4 years (Fig. 2). Three adult hawks died on fall or winter ranges (1 shot, 1 accidental, 1 unknown cause), and 3 died on breeding areas (1 human-caused, 1 unknown cause, 1 coyote predation) (Fig. 3).

Cumulative survival of juvenile hawks declined sharply within 4 months following fledging to

Table 1. Fate and survival time of telemetered ferruginous hawks captured in southcentral Washington, 1999–2002 as of September, 2003. Fate was determined from last observation, PTT location and PTT activity information. Post-capture survival time was determined from PTT activity information and from observations of telemetered or banded hawks after PTTs expired. Survival time is minimum for hawks known to be alive at last observation and those with unknown fates.

Age	PTT ID	Fate	Survival (mo)	Comment
Adult	15226	Alive	61	Bred 5 seasons
	15218	Unknown	25	Did not return to breed after 2001; PTT expired
	15217	Dead	3	Broken leg; died on fall range in 1999
	15186	Dead	46	Coyote predation on territory
	15228	Alive	60	Bred 5 seasons
	15185b	Unknown	18	PTT expired prematurely; alive at last broadcast
	10394	Dead	14	Stationary PTT; presumed dead, unknown cause[a]
	15184b	Alive	13	Bred 2 seasons
	15227	Dead	7	11.5 years old at death; unknown cause of mortality
	15185	Dead	6	Shot on winter range[b]
	15184	Alive	61	At least 13 years old, bred 5 seasons
	15216	Dead	12	Died on breeding territory; presumed human-caused[c]
	16652	Unknown	6	PTT expired prematurely; alive at last broadcast
Juvenile	10372	Alive	26	Alive when PTT expired
	10379	Dead	1	Probable starvation
	15227b	Alive	<1	PTT removed to test function
	15226b	Alive	13	Alive when PTT expired
	15186b	Alive	6	PTT expired prematurely; alive at last broadcast
	15527c	Dead	1	Shot
	15218b	Alive	1	PTT expired prematurely; alive at last broadcast
	15217b	Dead	1	Starvation
	15216b	Alive	13	
	15185c	Dead	5	Unknown cause of mortality
	10372b	Dead	1	Probable starvation
	15218c	Alive	12	
	15227d	Dead	1	Starvation
	16652b	Dead	5	Unknown cause of mortality
	15217c	Dead	1	Coyote predation prior to migration

[a]Hawk displaced from territory by another male in second season before mortality.
[b]Unbanded mate with distinct light morph plumage returned to territory 4 seasons but remained unpaired.
[c]Hawk disappeared abruptly 1 week before young fledged; 3 nestlings succumbed.

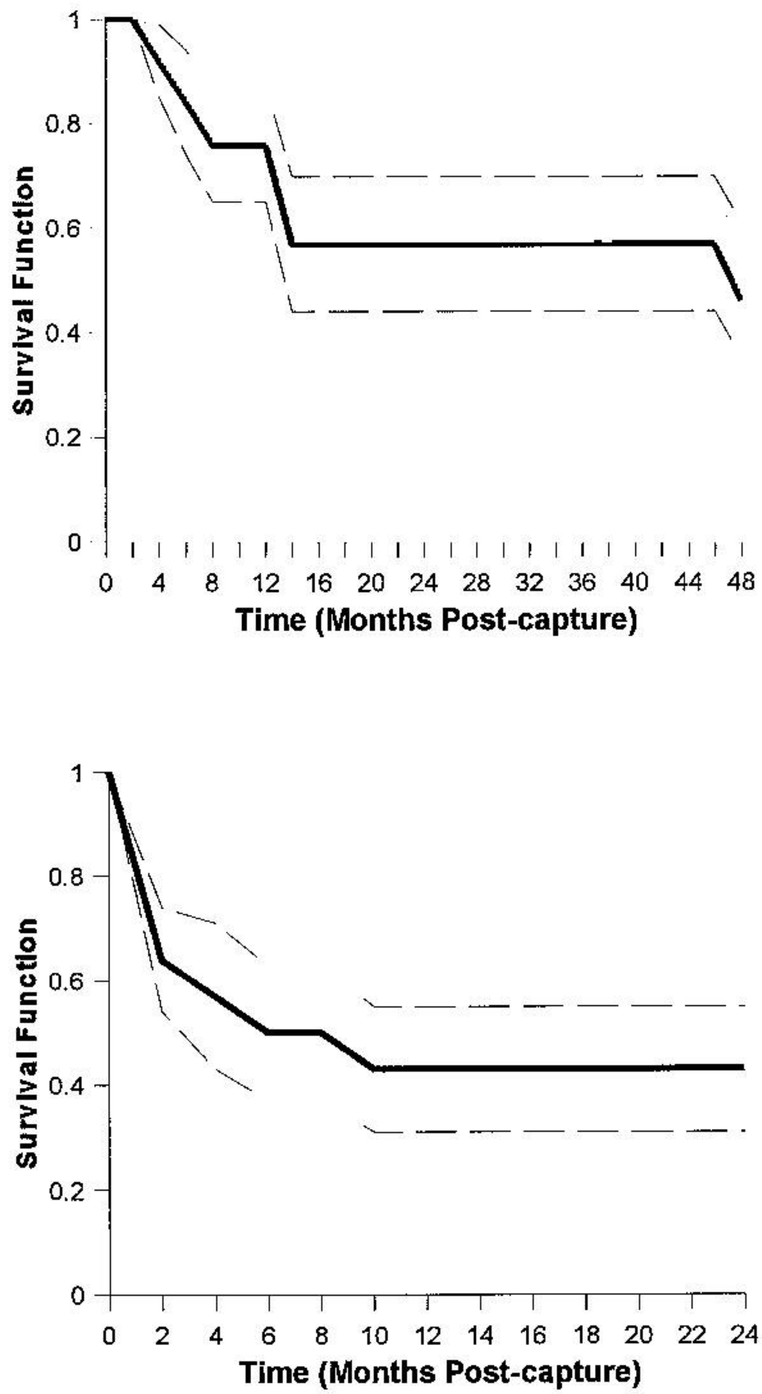

Fig. 2. Kaplan-Maier survival estimates (±95% CI) of telemetered adult (top) and juvenile ferruginous hawks (bottom) in Washington, 1999–2003. Hawks were captured in June.

0.43 (±0.10) at the first through the second year (Fig. 2). Three hawks died on their natal territories after fledging and prior to migration in June and July (Fig. 3). Two of these birds starved and 1 was depredated by a coyote, in spite of the presence of both adults on the territories. Two other hawks died during migration <1 week after leaving their natal territories in July and August (1 shot, 1 probable starvation). Three juveniles died on the fall or winter ranges 1 week to 5 months after migration from unknown causes. Overall, juvenile mortality occurred an average of 56 days (SD ± 58) post-fledging. Two of 9 banded juveniles that were not telemetered also died from starvation prior to migration (Appendix A, Table 2).

PTTs were still attached to 2 breeding adult males 5 years post-capture without apparent detrimental effects, and a PTT was recovered from female 15184 after she bred successfully 3 seasons. There were no signs of feather wear of abrasion from harness straps on birds recaptured live or recovered dead.

Adult Migration

Overview.– Eight adult hawks were monitored for at least 1 complete migration, and 5 adult hawks were monitored for a portion of migration (Appendix B, Fig. 1-13). Complete migration of adult ferruginous hawks was across latitudinal and longitudinal gradients (Table 2). Migration was generally in a clockwise pattern, to the north, south, west, and return north, but there were differences between the sexes. Four of 5 females migrated in a loop pattern and passed through or became localized in Central Plains during winter (Fig. 4). Rather than migrating through the Central Plains, males returned to territories or moved southwesterly creating a "figure 8" pattern (Fig. 4). Two males (15226 and 15184b) returned to their territories for 1 and 67 days before flying to winter ranges further south, and a third hawk (15186) returned to and remained on his territory each of 2 winters after migrating to North Dakota. Direct comparison of complete migration distance between males and females was not possible because 6 hawks either died on winter areas or suffered PTT failure. Assuming these hawks would have returned directly to territories in Washington from winter ranges (as did surviving adults), females migrated an average of 1360 ± 490 km further (paired t = 2.78, 13 df, $P = 0.016$) than males. Complete migration for 10 adult hawks averaged 3882 ± 336 km (range 2918–5788). For 16 combined winters during which the 13 hawks were monitored, adult hawks were in migration 13 ± 2% of the time they were absent from nesting territories. Time away from breeding ranges averaged 179 ± 16 days/year (range 32245 days).

PTTs functioned for a portion or all of a second season for 6 hawks. Four hawks used identical fall and winter ranges both years, but fall ranges were about 100 km and 200 km apart for the other 2 hawks from the first to second year. Overall, however, migration patterns for individuals were markedly similar between years, with hawks returning to the same major geographic region (e.g., Great Basin, Central Plains, etc.) each year (Fig. 4).

Summer Migration and Fall Ranges. –On average, adult hawks migrated from their territories the second week of July and arrived on fall ranges 5 days later (range June 19–July 27; Table 3). Average migration to fall ranges was quick and short compared to migration to winter

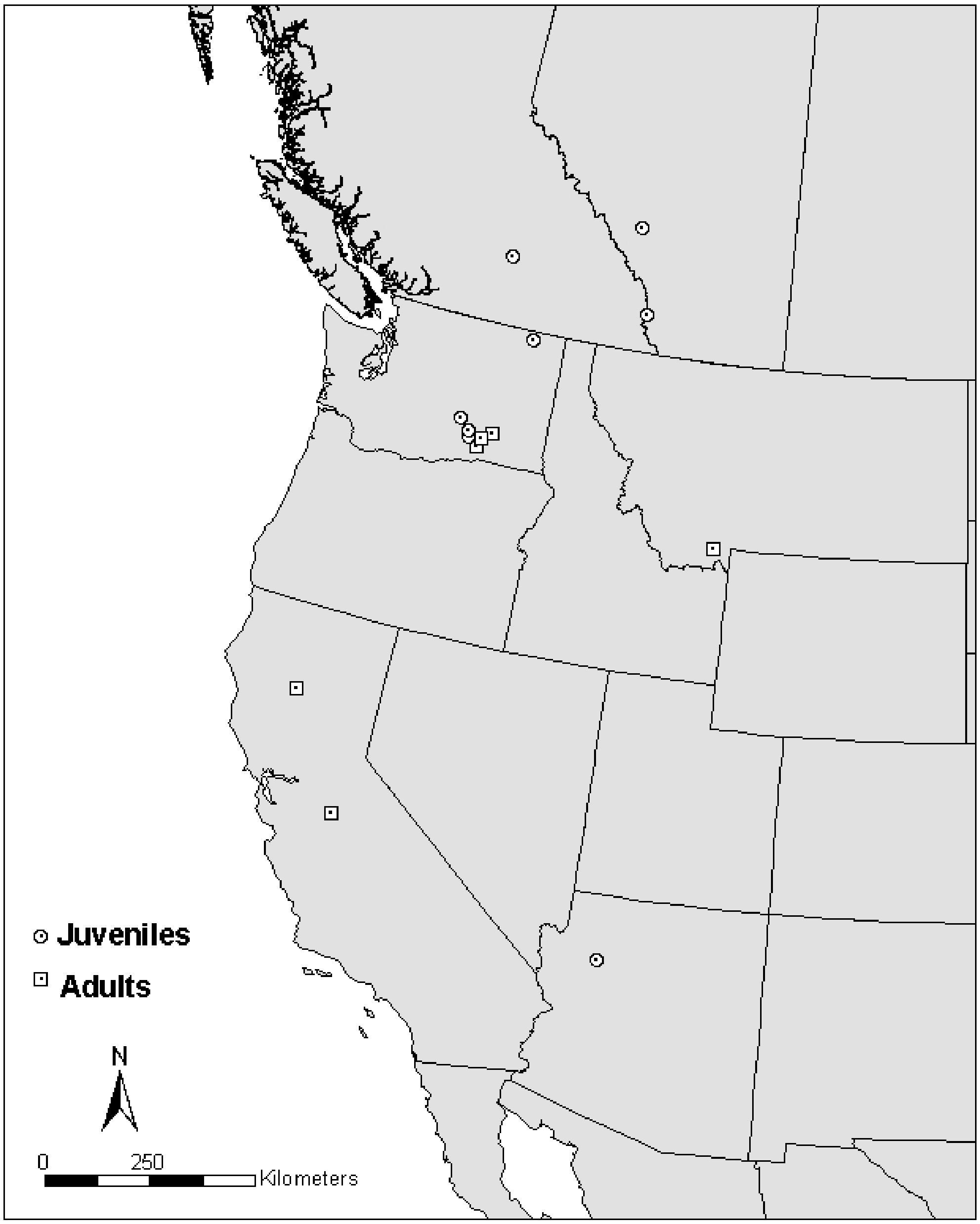

Fig. 3. Locations where telemetered juvenile and adult ferruginous hawks died between 1999 and 2003.

Table 2. Timing and patterns of movement of adult ferruginous hawks from and to breeding territories in south-central Washington 1999–2003. Locations where hawks became localized for≥5 days are indicated. For hawks that returned to territories in the spring the last location identified is the wintering area.

ID	Year	No. Yng	Last Fledge Date	Adult Departure Date	Adult Return Date	Migration Pattern
15226	1	2	7/18[a]	7/18	2/25/00[b]	Banff AB, Edmonton AB, territory, Sacramento CA, LaGrande OR, Sacramento, CA
15226	2	2	6/29	6/13-22	unknown	Lethbridge, AB, Banff AB, Sacramento CA
15218	1	1	6/18	7/27	3/18/00	Provo UT, Cedar City UT, Carrizo Plain CA
15218	2	1	6/21	7/8-23	unknown	Pocatello ID, Fairfield ID, Carrizo Plain CA
15217	1	2	6/30	7/22	mortality	Ennis MT
15186	1	4	6/25	7/12	11/17/99	Cardston AB, Bismark ND, Lewiston MT
15186	2	0	n/a	7/1	11/5/00	Cardston AB, Dickinson ND, Manning ND
15228	1	4	6/14	7/13-18	3/13/00	Cypress Hills SK, Helena MT, Shoshone ID, Willows CA
15228	2	0	n/a	7/18	3/4/01	Cypress Hills SK, Snake River ID, Willows CA
15228	3	0	n/a	7/18	unknown	Cypress Hills SK
15185b	1	0	n/a	7/5	n/a	Rapid City SD, Buffalo SD
10394	1	3	7/9	7/23	3/6/01	Salt Lake City UT, Raft River Valley ID, Park Valley UT, Bakersfield CA
15227	1	2	6/14	7/2	mortality	Browning MT, Ogallala NE, Red Bluff CA
15185	1	4	6/27	6/27-7/2	mortality	Browning MT, Stockton CA
15184	1	3	6/28	6/29[b]	3/1/00	Waukon WA, territory, Cutbank MT, Salida CO, Stockton CA
15184	2	2	6/22	7/3-11	unknown	Chester MT, Stockton CA
15216	1	3	6/19	7/2	3/10/00	Browning MT, Cardston AB, Guymon OK
16652	1	1	6/29	7/1/00[c]	unknown	Snake River ID, territory, Snake River ID, Cypress Hills, SK, Boulder CO, Brighton CO
15184b	1	1	6/16	7/23	3/4/03	Dupuyer MT, territory, Sacramento CA
15184b	2	0	n/a	7/9	9/23/03[d]	Dupuyer MT, territory

[a]Both young died 1-2 days post-fledging
[b]Bird exhibited pre-migratory movement 161 km northeast on 6/16/99, and returned to territory 6/21/99 (young still unfledged).
[c]Bird exhibited pre-migratory movement 393 km southeast on 6/16/00 and returned to territory 6/22/00 (young still unfledged).
[d]PTT still active at time of report summary, had not moved to winter range as of this date.

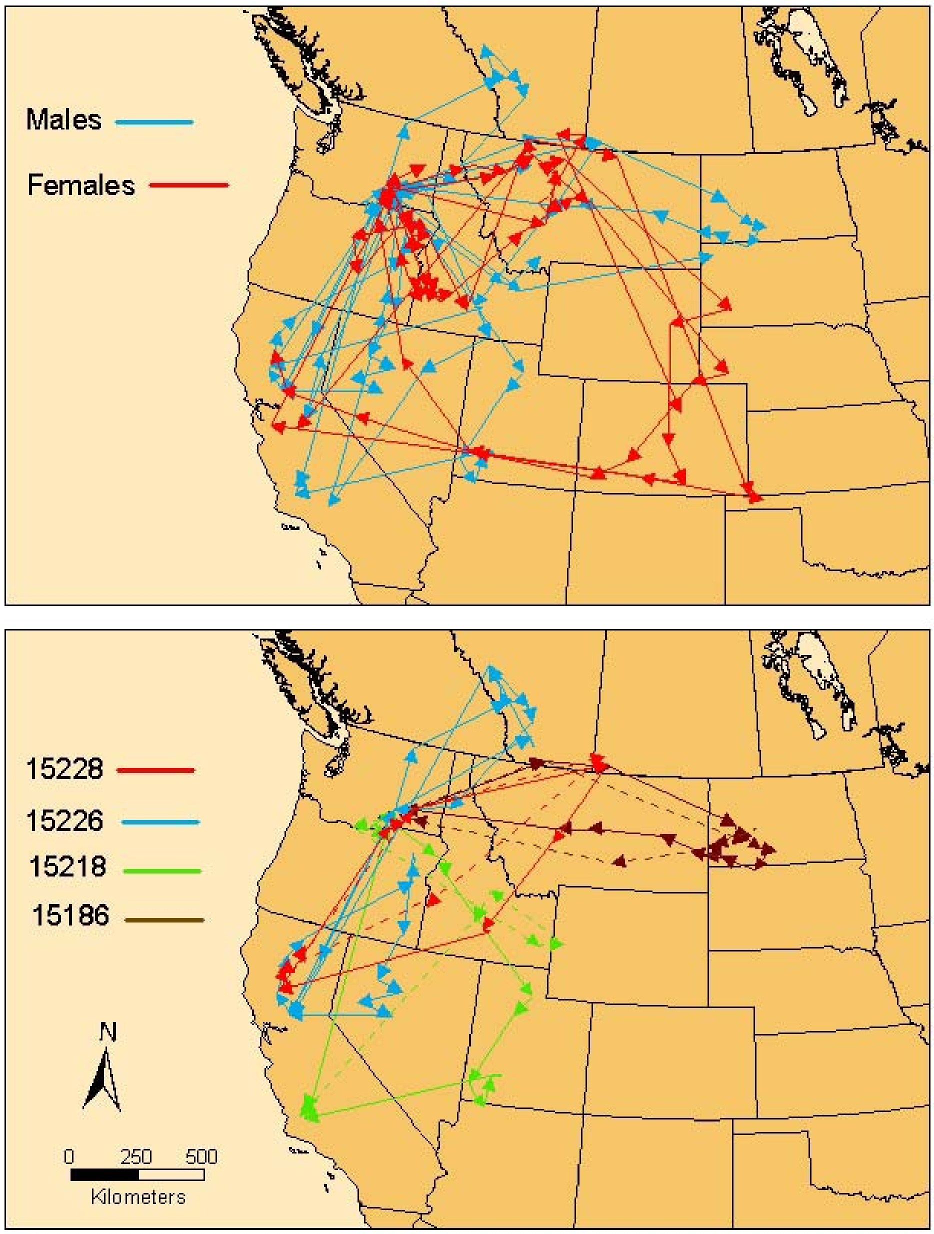

Fig. 4. (Top) Migration patterns of 13 adult ferruginous hawks from southcentral Washington. For hawks monitored 2 years, only the first migration is shown. (Bottom) Complete migration of 4 adult male ferruginous hawks in 2 successive years depicted by solid and dashed lines.

Table 3. Migration statistics of 13 adult and 11 juvenile ferruginous hawks from south-central Washington, 1999–2003 (± SD).

Origin/destination	*n*	Date (leave, arrive)	Duration (da)	Distance Traveled (km)	Rate (km/da)
Adult					
Nest site/fall range	18	July 9 ± 11, July 14 ± 11	5 ± 3	831 ± 512 (range 512–2,682)	245 ± 160
Fall range/winter range	22	Sept 22 ± 34, Oct 1 ± 35	10 ± 7	1,336 ± 774 (range 135–3,548)	189 ± 177
Winter range/nest site[a]	8	Feb 24 ± 6, March 5 ± 7	9 ± 5	1,248 ± 523 (range 833–2,304)	174 ± 110
Juvenile					
Nest site/winter range	11	July 21 ± 10, Oct 16 ± 10	90 ± 15	6,139 ± 3,156 (range 2,690–10,092)	69 ± 36
Winter range/breeding range[b]	4	March 28 ± 38, June 25 ± 68	90 ± 86	1,522 ± 269 (range 1,278–1,905)	70 ± 82

[a]Excludes hawk 15186 that returned to his territory in November and remained throughout winter.

[b]No juvenile hawks bred during the year following hatching, but juveniles occupied areas throughout the known breeding range of the species.

Table 4. Occupancy (days on range, ± SD) and size (km^2, ± SD) of seasonal ranges used by 13 adult ferruginous hawks from Washington. Ranges were 100% minimum convex polygons estimated from class 1–3 satellite locations.

Area	Fall Ranges				Winter Ranges			
	n	Days	*n* loc	Size	*n*	Days	*n* loc	Size
Northern Plains	8	68 (16)	13 (7)	507 (642)	0	-	-	-
Rocky Mountains	11	38 (18)	17 (13)	349 (365)	0	-	-	-
Great Basin	2	56 (13)	24 (6)	2,392 (1,118)	0	-	-	-
Columbia Plateau	8	17 (23)	7 (5)	465 (748)	1	56 (66)	5	563
Central Plains	1	26	12	180	2	115 (71)	16 (1)	48 (35)
California Trough	1	1	-	-	11	108 (39)	24 (14)	173 (145)

ranges and spring migration back to nesting areas (Table 3). Timing of migration from territories was related to the date the young fledged, and was different between the sexes (paired t = 3.21, 9 df, $P = 0.011$) with females migrating earlier (± SE = 10 ± 3 days postfledge) than males (± SE = 26 ± 3 days postfledge). Two females, 15184, and 16652, dispersed 161 and 393 km from nests for a few days before young fledged, returned to territories for a few days, and migrated soon after young fledged (Table 2). Adult males remained on territories and provisioned food for young after females migrated. Adults and young migrated independently.

Initial migration for 10 hawks (77%) was northeasterly or easterly across the Continental Divide to the east slope of the Rocky Mountains, and subsequent movements in fall for 3 hawks were to the Northern Plains (Fig. 5). Initial migration for 3 hawks (23%) was southeast to the Great Basin. Longitudinal and northward migration appeared to be a functional response to prey. In grasslands along the Rocky Mountain front in Alberta, Montana, and Saskatchewan, ground reconnaissance found ferruginous hawks feeding extensively on abundant Richardson's ground squirrels (*Spermophilus richardsoni*) near highways, grazed pastures, and on edges of native grassland in disturbed soils (e.g., fencelines) (pers. obs.). Most telemetered hawks on fall ranges were associated with other ferruginous hawks, sometimes 3 or 4 hawks sharing the same field or ground squirrel carcass, or dispersed individuals over larger, but distinct geographic areas of undisturbed native grassland, grazed grassland, and broken native habitat and agricultural land. For example, in 1999 counts of hawks along 80 km of highway between Browning, Montana and Cardston, Alberta where 3 telemetered hawks spent the fall averaged 1 ferruginous hawk/km. Similar counts along 40 km of highway 287, in southwest Montana in the Madison River Valley, averaged 2 ferruginous hawks/km. The fall range of hawk 15226 along the front of the Rocky Mountains was an exception; this bird migrated across British Columbia (as did several juvenile hawks, see juvenile summer migration below) and resided in aspen (*Populus tremuloides*) parkland along the Rocky Mountain front for 46 days, presumably feeding on Columbian ground squirrels (*S. columbianus*) (J. Allen, pers. comm.). Fall ranges in the northern Great Plains (i.e., North Dakota, South Dakota, and Nebraska) were associated with pocket gophers (Thomomys spp.) and other small mammals (e.g., 13-lined ground squirrels *S. tridecemlineatus*) in grazed grassland or fallow farmland, but small colonies of black-tailed prairie dogs were also near these locations (pers. obs.; T. Melum, W. Cornatzer, M. Erickson, J. Dinan, pers. comm.). Ferruginous hawks on 3 fall ranges in the Great Basin were not observed to forage during ground observations. However, this habitat in eastern Oregon, south-central Idaho, and northern Utah was shrubsteppe, pasture, and agriculture, that supported black-tailed jackrabbits, pocket gophers, meadow voles (Microtus spp.), and Paiute ground squirrels (*S. mollis*) (P. Makela, E. Yensen, M. Todd, and S. Findholt, pers. comm.).

Based on pooled activity time (*n* = 1,195 hawk-days), adult hawks spent >75% of their time during fall in the Northern Plains and front range of the Rocky Mountains, 20% of their time in the Great Basin and Columbia Plateau, and <3% of their time in the Central Plains and California Trough (Fig. 6). Mean number of days spent on fall ranges was also higher for hawks in the Northern Plains than in other areas (Table 4). However, the largest ranges were in the Great Basin (Table 4). The average number of days adult hawks spent on fall ranges (50 ± SE =

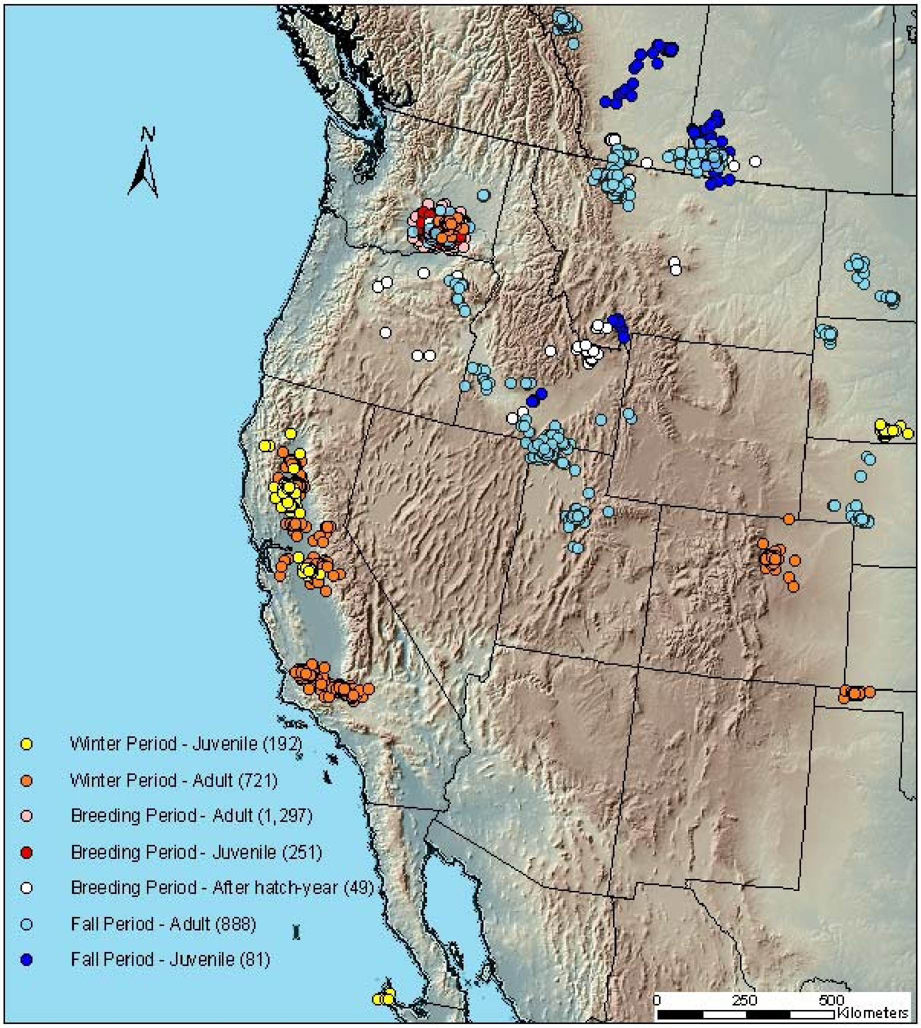

Fig. 5. Ranges used by adult, juvenile, and after hatch-year ferruginous hawks telemetered in Washington. Breeding season ranges were occupied from March to mid-July, fall ranges from mid- July to August, and winter ranges from September to February. Parentheses indicate number of satellite locations.

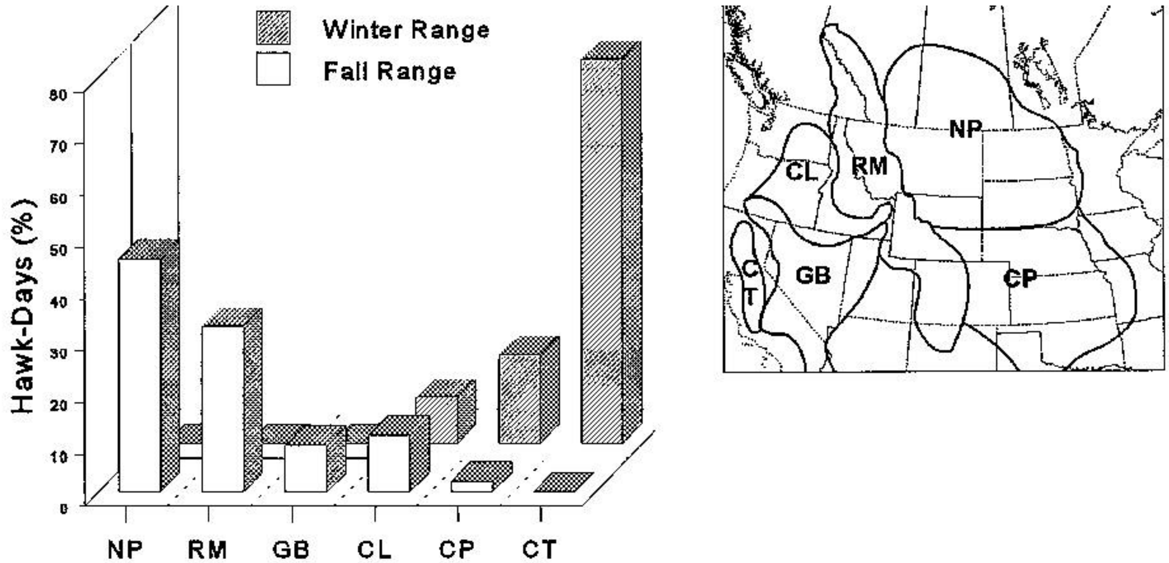

Fig. 6. Time budgets of adult ferruginous hawks from Washington state on fall ranges (n = 1,195 hawk-days) and winter ranges (n = 1,316 hawk-days) in western North America. NP = Northern Plains, RM = Rocky Mountains, GB = Great Basin, CL = Columbia Plateau, CP = Central Plains, and CT = California Trough.

5) was less (t = 5.40, 41 df, $P < 0.0001$) than time hawks spent on winter ranges (101 ± SE = 13). However, mean size of fall ranges (954 km^2 ± SE = 170) was greater (t = 1.69, 31 df, $P = 0.101$) than size of winter ranges (307 km^2 ± SE = 55).

Hourly migration rates were determined from 12 periods of 7 adult hawks lasting 4 to 11 hours where quality locations (i.e., class 1–3) allowed accurate estimation of distances moved. Migration rate ranged from 5 to 51 km/hr. Hawks crossed the Continental Divide at several different passes, primarily in western Montana (Fig. 7). Although exact locations of passage were not always certain (i.e., crossing was plotted by connecting the line between 2 nearest points on opposite sides of the Divide), some passes appeared to have been used by more than 1 migrating hawk (i.e., Roger's Pass northwest of Helena). There did not appear to be any consistent patterns of passage for adult or juvenile hawks.

Fall Migration and Winter Ranges.–All adult ferruginous hawks migrated again by the end of November to winter ranges, an average of 1,336 km from fall ranges. Winter ranges of 8 hawks (73%) were located in the California Trough, 2 (18%) in the Central Plains, and 1 (9%) in Washington state (Fig. 5). Based on pooled activity time (n = 1,316 hawk-days), 74% of pooled activity time was spent in the California Trough (Fig. 6). Hawks in the central valley of California were located in grazed native grassland or Oak Savanna interspersed with agricultural land or almond orchards (B. Latta, C. Gill, D. Walker, M. Smith, J. Pagel pers. comm.); all areas

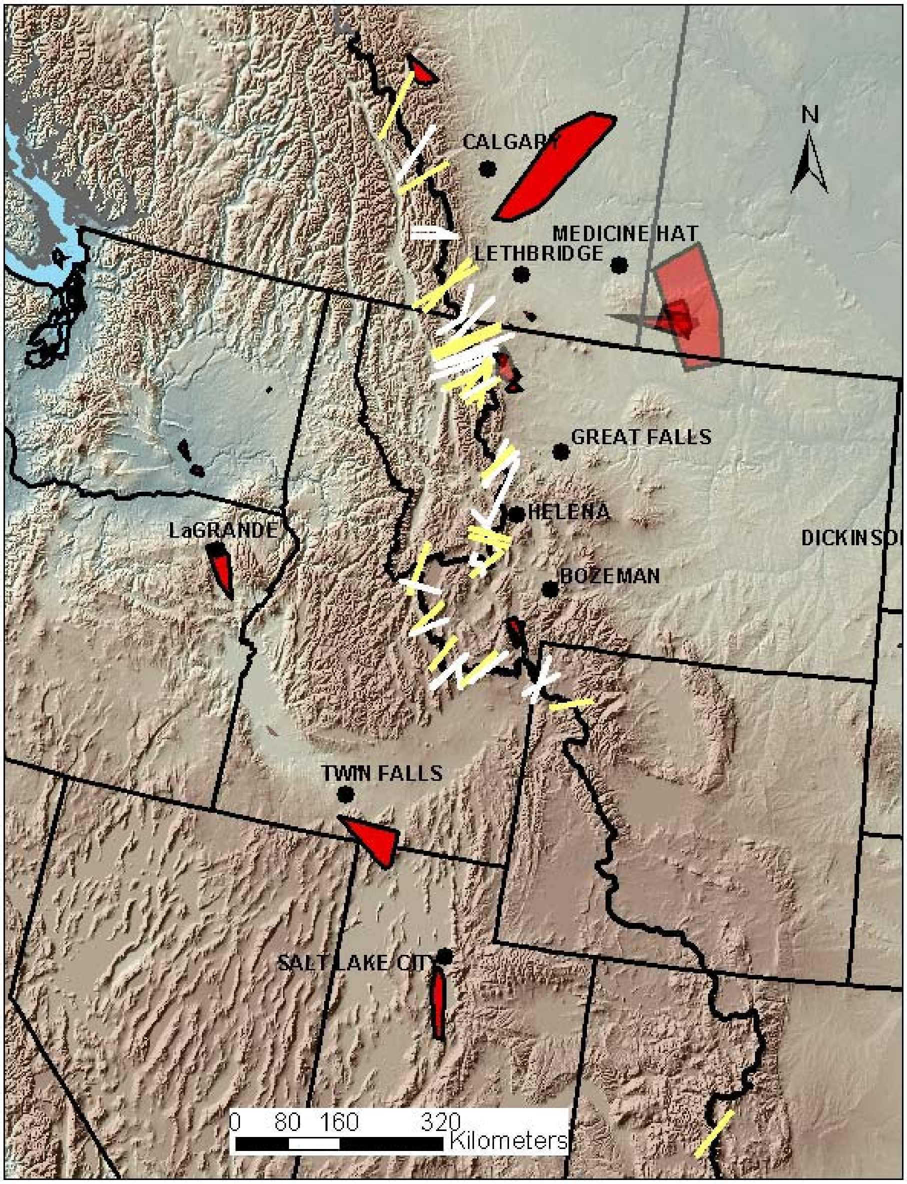

Fig. 7. Locations at which adult (yellow lines) and juvenile (white lines) ferruginous hawks crossed the Continental Divide after migration from Washington state. Orange polygons represent fall ranges of adults (100% minimum convex polygons) estimated from class 0-3 satellite locations.

had a high abundance of California ground squirrels (*S. beecheyi*). The Carrizo Plain, at the southern extent of the valley where hawk 15218 wintered 2 years, vegetation was primarily annual grassland with saltbush scrub where California ground squirrels, San Jouquin Antelope squirrels (*Ammospermophilus nelsoni*), and black-tailed jackrabbits are common (R. Stafford, S. Fitton, pers. comm.). Ferruginous hawks have been observed feeding on giant kangaroo rats (*Dipodomys ingens*) in the plain (S. Fitton, pers. comm.).

In the Central Plains, winter habitat of hawk 15216 near Guymon, Oklahoma was mixed irrigated agriculture and sandsage/gamma grass rangeland (M. Howery, pers comm.). Black-tailed prairie dogs, and desert cottontails (*Sylvilagus audubonii*) were common within the winter range of this hawk (M. Crocker, pers. comm.). Hawk 16652, which wintered in the front plains of Colorado located in areas of grassland and pasture near Boulder and near the Rocky Mountain Arsenal, with high densities of black-tailed prairie dogs (pers. obs).

In the Columbia Plateau, hawk 15186 wintered on his breeding range in the Washtunca Coulee of southcentral Washington during 2 years. This hawk wintered at a latitude of 46 degrees north, whereas all other hawks were south of the 41st parallel (Fig. 5).

Spring Migration and Breeding Ranges.–Adult ferruginous hawks migrated back to breeding territories in late February and early March (Table 3). For 9 hawks that were monitored for at least 1 year, there was a 100% return rate to their previous breeding territories (Table 1). Further, 3 of these hawks nested 5 years on the same territory after expiration of their PTTs. Telemetered hawks nested on the same territory during 22 pooled breeding seasons where PTTs were either active or had expired. All territories where telemetered adults died or where hawks disappeared with unknown fates were left unoccupied or reoccupied by unmarked adults. The mate of female 15185, recognized by distinct plumage characteristics, remained unmated 4 years after her death.

Juvenile Migration

Summer Migration and Fall Ranges.–Nine of the 11 juveniles that survived the post-fledging period migrated initially north or northeast to Canada (7) or Montana (2) (Table 5; Appendix B Figs. 14 through 19). Two juvenile hawks migrated initially to Idaho and Nevada. Average departure date was the 3rd week of July (Table 3).

Summer migration of juvenile hawks was characterized by high mortality shortly after dispersal (Fig. 2). Only 4 of 11 hawks (36%) that migrated were known to survive at least 1 year. Four of the 7 juveniles that moved initially to Canada died or were lost from radio contact within several days of dispersal (Table 1) as they passed into or flew over the Rocky Mountains from British Columbia (Appendix B, Fig. 18 and 19). Passage along the Continental Divide in Canada and Montana was widely dispersed among juveniles (Fig. 7).

For surviving juveniles, migration was characterized by extensive, wide-ranging movements the first fall. The 4 juvenile hawks made multiple visits to widely separated geographic areas (Table

Table 5. Timing and movement patterns of juvenile ferruginous hawks from natal territories in southcentral Washington, 1999–2003. Locations where hawks remained for 5 days are indicated. Date of the beginning breeding season during the second year was determined on the date after hatch-year birds migrated from winter ranges, and ended when they migrated to winter ranges. The last location for each fall/winter season is the wintering area for hawks that are not identified as mortalities.

ID	Year	Season	Departure Date	End Date	Pattern
10372	1	Fall/winter	7/14/99	4/8/00	Ennis MT, Winnemucca NV, Gooding ID, Napa CA, Shoshone ID, Modesto CA
10372	2	Breeding	4/9/00	7/23/00	Jerome ID, Lima MT, Monida MT
10372	2	Fall/winter	7/27/00	3/15/00	Lewiston MT, Burley ID, Stockton CA
10372	3	Breeding	3/20/01	7/28/01	Saddle Mountain NWR WA, Cardston AB, La Grande OR
10379	1	Fall/winter	7/23/00	8/1/00[a]	Banff AB
15226b	1	Fall/winter	7/14/01	2/3/02	Calgary AB, Edmonton AB, Medicine Hat AB, Calgary AB, Cardston AB, Calgary AB, Helena MT, Boise ID, Willows CA, Red Bluff CA, Browning MT, Lethbridge AB, territory, Harney Basin OR, Petaluma CA, Williams CA
15226b	2	Breeding	2/3/02	7/4/02	Unknown
15226b	2	Fall/winter	7/5/02	7/15/02	Lethbridge AB
15186b	1	Fall/winter	7/13/01	7/14/01[b]	Calgary AB
15227c	1	Fall/winter	7/30/01	mortality	Sicamous BC
15218b	1	Fall/winter	8/13/01	9/07/01	LaCrosse WA, territory, Pullman WA, Idaho Falls ID
15216b	1	Fall/winter	7/17/02	5/7/03	Cypress Hills SK, Red Owl SD, Rosebud Indian Res. NE
15216b	2	Breeding	5/8/03	8/9/03	Cypress Hills SK, Lethbridge, AB
15216b	2	Fall/winter	8/10/03	9/2/03[c]	Rosebud Indian Res. NE
15185c	1	Fall/winter	7/18/02	mortality	La Grande OR, territory, Mohave Desert NV
10372b	1	Fall/winter	7/10/02	mortality	Methow WA, Kettle Falls WA
15218c	1	Fall/winter	7/23/02	4/22/03	Wallowa OR, White Sulphur Springs MT, Stockton CA, Yellowstone MT, Grand Canyon AZ, Vizcaino Desert MX, Stockton CA
15218c	2	Breeding	4/23/03	7/15/03	Malheur OR
15218c	2	Fall/winter	7/16/03	9/5/03[c]	Dupuyer, MT
16652b	1	Fall/winter	7/24/02	7/28/02[d]	Lethbridge AB

[a]Mortality by date indicated.

[b]Apparent PTT failure.

[c]PTT still active at time of report summary.

[d]PTT signal lost until mortality confirmed in November.

1), and were distributed throughout the same areas where adults also spent the fall (Fig. 5; i.e., Northern Plains, Rocky Mountain foothills, Snake River Plain, and Central Plains). However, because juveniles moved continually over great distance in the fall, averaging 69 km/day, individuals did not occupy relatively small, well-defined fall ranges as did the adults. On average, juvenile hawks moved 6,139 km during the 90 days prior to settling on winter ranges (Table 3). Two juveniles, both females, passed a few kilometers from their natal territories while in transit between fall ranges.

Four related adult and juvenile hawks were monitored during migration. All birds, except 1 adult and juvenile female, were telemetered during the same year. No telemetered siblings survived to migration. Related adults and juveniles dispersed to different geographic regions; initial dispersal for 3 of 4 related pairs of birds was to different sides of the Continental Divide (Fig. 8). The only juvenile to survive through at least 1 winter migrated to the same general geographic regions as her mother including northern Montana, southcentral Idaho, and central California (Fig. 8b). Neither adult or juvenile occupied the same specific location during the same period.

Spring Migration and Breeding Period Movements.– On average, the 4 surviving juvenile hawks arrived on winter ranges by mid-October (Table 3). Juveniles wintered in the California Trough, south-central Nebraska and the Baja Peninsula, Mexico (Fig. 5). Departure from winter ranges was, on average, a month later for juvenile (technically after-hatch year or immature) hawks compared to adults (Table 3). The average distance immature hawks moved their first spring (1,522 km) was much more similar to that of the adults in spring (1,248 km) relative to their comparative fall movements (Table 3). Immature hawks did not nest, but moved to the Pacific and interior northwest during the breeding period (Fig. 5). No immature hawks returned to south-central Washington during the breeding period. On average, immature hawks arrived on ranges they used during the breeding period near the end of June (Table 3).

The total distance 2 juvenile hawks moved during the first fall from their natal territories before arriving on the winter range was an average of 2,265 km more than the total distance moved by same birds their second fall (as immatures) from the breeding range to the same winter areas. A third hawk had not arrived on the winter range at the time these data were summarized.

DISCUSSION

Adult ferruginous hawks from Washington made 2 distinct migrations before arriving on winter areas. Post-nesting migration of hawks to fall ranges was a functional response to prey availability, principally (75%) Richardson's ground squirrels. Richardson's ground squirrels provided a widespread and dependable annual food source for this population. For most hawks post-nesting migration was quick, strongly longitudinal, and traversed the Continental Divide over the Rocky Mountains. These factors evidenced a strong drive in hawks to replenish fat reserves that were depleted during nesting prior to winter. This may be particularly important for females whose stored fat reserves are used to lay eggs, and for warmth during incubation and brooding.

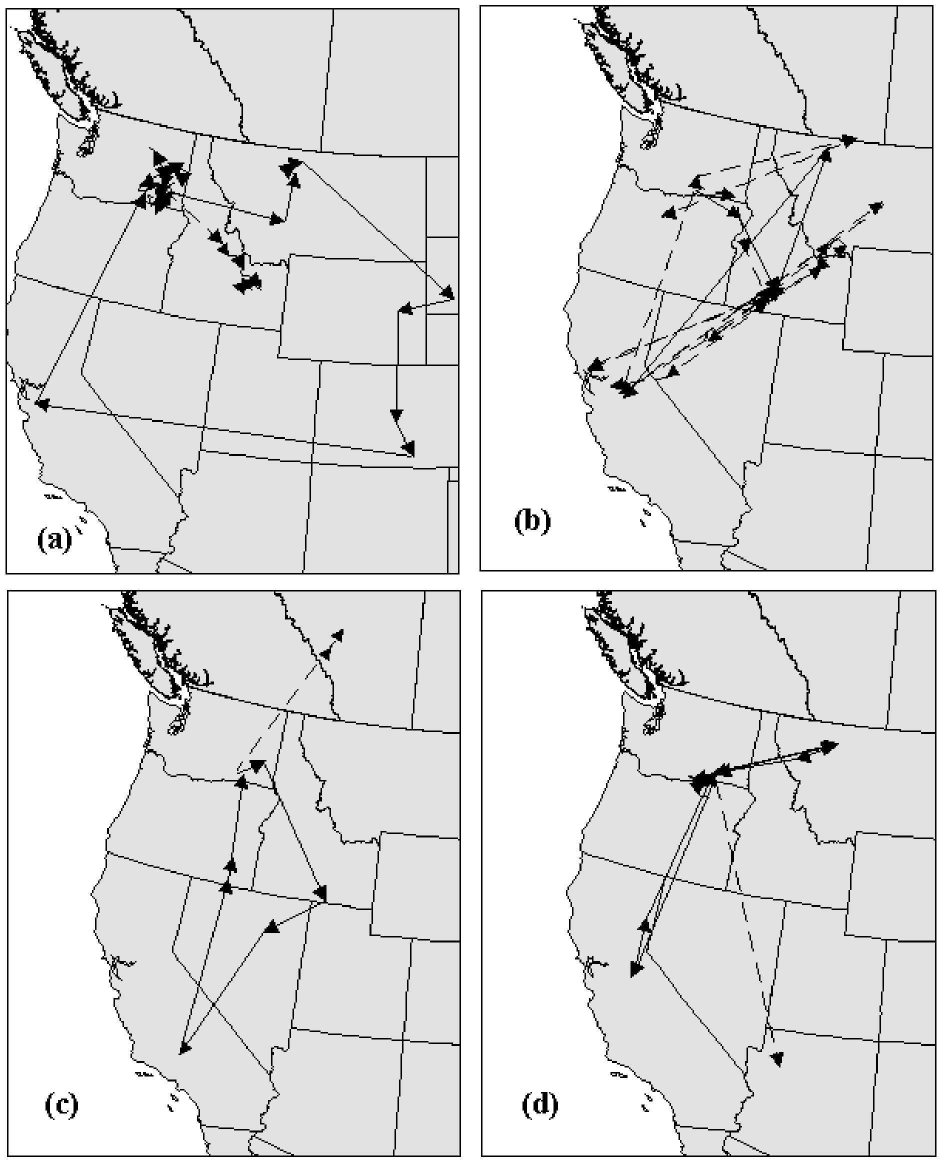

Fig. 8. Migration of related adult (solid lines) and juvenile (dashed lines) ferruginous hawks from south-central Washington. (a) Territory 184, adult female 15184 (1999-2000) and juvenile female 15218b (2001). (b) Territory 301, adult female 15185 and juvenile female 10372 (both 1999-2000). (c) Territory 162, adult male 10394, juvenile male 10394 (both 2000-2001). (d) Territory 87, Adult male 15184b and juvenile female 15185c (both 2002-2003).

A study of the European sparrowhawk (*Accipiter nisus*) indicated females increase their body weight by 15% which is assimilated during the nesting process (Newton 1986). The urgency of migration for some female ferruginous hawks was indicated by their pre-migration dispersal movements and migration immediately after young fledged. For males, prolonged occupancy of the territory was a consequence of more obvious needs: to feed the fledged young to dispersal after females migrated. Migration theory also predicts that males, as primary defenders of nesting territories, gain an advantage in maintaining territories if they remain longer (Mueller et al. 2000). Distinct post-nesting migration is not unique to Washington ferruginous hawks, nor are premigratory excursions. Similar movements have been seen in telemetered ferruginous hawks from the Northern and Central Plains (unpubl. data), and the Great Basin (M. Fuller, pers. comm.). It is unknown if Washington's hawks migrated as extensively and to the same fall destinations historically, or whether a greater percentage of fall migrants may have remained west of the Continental Divide in Washington or the Great Basin when ground squirrels were locally abundant. Dramatic depletion of native ground squirrel populations in Washington during the past 50 years is likely responsible for a shift in food habits of the breeding ferruginous hawk population to pocket gophers, reptiles, and insects (Richardson et al. 2001). Alternatively, the front range and Northern Plains may always have been a magnet for post-breeding ferruginous hawks, and because those nesting in Washington are on the periphery of the northern breeding range, they must traverse the Rocky Mountains to take advantage of it. This may be a factor limiting the nesting range of the species in the northwest. Ferruginous hawks nesting in southern Alberta remain on their breeding ranges to take advantage of this prey source post-nesting, and those in North Dakota and probably other areas of the Northern Plains disperse northward before migrating south until after the last ground squirrels enter estivation in fall (Schmutz et al. 1979, Gilmer 1985, Schmutz and Fyfe 1987). Similarly, migration timing and location of ferruginous hawks in the Snake River Plain in Idaho appear to be regulated by the timing of estivation of Richardson's ground squirrels at different elevations (Thurow et al. 1980, Gerstell and Trost 1995). Because juvenile Richardson's ground squirrels are often the last age class to estivate (by late September, U. Banasch, pers. comm.), grass conditions in spring, adequate rainfall, and resulting ground squirrel productivity are likely to be important influences on annual movements and health of Washington's ferruginous hawks along the Rocky Mountain front.

The Continental Divide was not a physical barrier to ferruginous hawk movements, although most hawks from Washington eventually wintered on the west side of the Rocky Mountains. Some hawks (especially juveniles) crossed the Rocky Mountains multiple times during a single season. Importantly, had band recoveries of Washington hawks from winter areas been the only means of identifying migration pathways, there would have been little evidence that Washington hawks ever crossed the Divide. The Continental Divide has been identified as a possible physical barrier between populations of ferruginous hawks on the east and west sides of the Rocky Mountains (Schmutz and Fyfe 1987, Warkentin and James 1988) based largely on the fact that very few ferruginous hawk band recoveries from eastern populations are from west of the Divide (Lincoln 1936, Salt 1939, Harmata 1981, Gilmer 1985, Schmutz and Fyfe 1987, Harmata et al. 2001). However, Gossett (1993) concluded there was no evidence of eastern and western subpopulations of ferruginous hawks based on an examination of morphological, genetic, and band recovery data. Thus, while it appears that the Continental Divide creates a natural boundary for latitudinal migration of most ferruginous hawk populations from the plains or Great

Basin, the energetic demands and hazards of crossing the Rocky Mountains to acquire prey are not prohibitive to some populations as part of the annual life cycle.

The second migration of Washington's adult ferruginous hawks was typically latitudinal and southward from fall to winter ranges, but sex of adult hawks influenced orientation and pathways. Migration of some male ferruginous hawks back onto breeding territories in winter was consistent with the tendency of some male Buteos and other male raptors to have a greater attachment to nesting places in winter than females (Schmutz 1977, Newton 1979, Mueller et al. 2000). Conversely, movement of females through grassland habitats, where black tailed prairie dogs are common ferruginous hawk prey (Cully 1991, Allison et al. 1995, Plumpton and Anderson 1998, Bak et al. 2001), may have resulted from differential prey selection by the sexes. Empirical evidence is lacking that ferruginous hawks may segregate by sex based on prey type or locale, yet the feeding efficiency hypothesis (developed in regard to Accipiter behavior) suggests that females will migrate earlier and further south than males because they hunt larger prey (Rosenfield and Evans 1980). Schmutz et al. (1991) examined prairie falcon (*Falco mexicanus*) band recoveries from western Canada and found 5 of 5 migrant males were recovered in northern latitudes of the winter range, compared to 11 of 19 females, but concluded the differences were not related to sex. Current satellite telemetry studies of ferruginous hawks in northern grasslands (unpubl. data) and Great Basin (M. Fuller, pers. comm.) will shed more light on whether sexual differences in migration patterns are a characteristic of the species.

The central valley of California was a critical winter region for hawks from Washington; 74% of pooled activity time on winter ranges was spent in the central trough of California. Milder winter weather and notable prey were characteristic of this Pacific zone south of the 41st parallel. California ground squirrels were very abundant at most telemetered hawk locations (M. Smith, J. Pagel, C. Gill, B. Stafford, D. Walker, G. Hunt, pers. comm.). California ground squirrels are unique among the *Spermophilus* because they do not estivate, or estivate infrequently (Evans and Holdenried 1943), and therefore are available to raptors throughout fall and winter. California is an important wintering area for ferruginous hawks west of the Continental Divide (Warkentin and James 1988, Garrison 1990), but there is no previous evidence that ferruginous hawks originating from Washington constituted any of the wintering population. Ten of fifteen band recoveries in California between 1939 and 1986 were from areas west of the Rocky Mountains, but none were from Washington (Garrison 1990). Also, ferruginous hawks banded in the Northern Plains and Great Plains, especially nestlings, rarely migrate to California (Lincoln 1936, Salt 1939, Harmata 1981, Gilmer 1985, Schmutz and Fyfe 1987, Harmata et al. 2001). Consequently, Washington hawks, and likely those from Oregon, account for a portion, perhaps a significant portion of the wintering hawk population in California. Two analyses of Christmas bird counts (CBC) from 1952 to 1984 (Warkentin and James 1988) and from 1949 to 1988 (Garrison 1990) found that ferruginous hawk numbers increased during those periods in California (Warkentin and James 1988). The former study speculated that breeding populations where hawks originated were likely increasing, but the latter study concluded that the increase largely resulted from new CBC routes in ferruginous hawk habitat and improved identification skills of observers. More recent analysis of CBC and migration data suggest ferruginous hawks are declining in western North America (Hoffman and Smith 2003).

Because adult hawks were away from breeding territories across multiple landscapes with a variety of potential mortality sources (e.g., gunshot, vehicle collision, poison) winter mortality was expected to be high. However, winter mortality was proportional (50%) to the amount of time hawks spent away from breeding territories (average of 179 days or 49% of the year). Shooting, electrocution, and collisions with vehicles which have been identified as important sources of direct mortality of wintering ferruginous hawks (Allison et al. 1995, Cartron et al. 2000, Bak et al. 2001, Harmata et al. 2001) were not consistent sources of mortality for Washington's ferruginous hawks, but some birds disappeared for unknown reasons. Gilmer (1985) found the recovery rate of banded ferruginous hawks >1 year old was significantly greater in winter, with shooting a significant cause of mortality. Indirect mortality, from factors such as fragmentation of habitat and associated loss of prey are not easily quantified, but expansive urbanization potentially affected health and survival of some hawks across large areas of traditional wintering habitat in the central valley of California and the front range of Colorado (M. Smith, pers. comm., Plumpton and Andersen 1998). There was no evidence that PTTs affected survival. Andersen (1994) concluded that reproductive success of ferruginous hawks and other Buteos telemetered with backpacks was comparable to that of unmarked hawks. Cumulative annual survival of telemetered adult hawks from Washington during 4 years post-marking (decline from 0.76 to 0.43) was comparable to the adult mortality rate of 25% that Woffinden and Murphy (1989) estimated based on allometrics for a declining population of Utah hawks (actual levels of mortality may have been even greater). Longevity documented for adult hawks in Washington (e.g., 11 and 13 years) was exceptional based on the 5.9 year average longevity Harmata et al. (2001) estimated for banded and telemetered hawks (Harmata et al. 2001), yet well less than the maximum recorded longevity of 18 to 20 years (Houston 1984, Newton 1989, Gossett 1993).

Satellite monitoring of juvenile hawks during the post-fledging period, and especially the first few weeks of migration, found these periods be survival bottlenecks for juvenile hawks. The survival rate dropped most precipitously during the first 4 months to 57%, but leveled off to 43% at 1 year, and was strikingly similar to the 66% first year mortality estimated for Alberta ferruginous hawks (Schmutz and Fyfe 1987). Mortality of juvenile ferruginous hawks banded in North Dakota was similar: 36% during the first fall, and 32% the first winter (Gilmer 1985). In Washington, starvation accounted for 38% of juvenile mortalities during post-fledging dependence, was quite likely a proximal cause of additional juvenile mortalities through winter, and was greater than an 86% post-fledging survival for Montana hawks (Zelanak et al. 1997). Starvation mortality appears to be common among nestlings and juveniles ferruginous hawks in Washington, and siblicide has been documented (unpubl. data). Food stress from local drought conditions are causes of siblicide and consumption of dead ferruginous hawk young by other siblings (Ensign 1983, Woffinden and Murphy 1977). Clutch size and number of fledged young for this species vary in synchrony with cyclic prey fluctuations (Smith and Murphy 1978, Smith and Murphy 1979, Steenhof and Kochert 1985, Schmutz and Hungle 1989), so starvation and siblicide are density-dependent factors that reduce nesting success during low prey years. All Washington juveniles that survived the post-fledgling period to dispersal appeared well-provisioned and robust, but many did not survive initial dispersal, particularly over the Rocky Mountains northeast through British Columbia. In 1 instance, a juvenile hawk spent several days in an apparently errant northwesterly orientation, only to succumb within a week when he finally reached the foothills of the Rockies to the northeast (hawk 10372b, Appendix B Fig. 18). The need for juveniles to quickly establish foraging independence is likely exacerbated by the energetically expensive flight that took many juveniles over Rocky Mountains. Survival of immature hawks remained at 43% through their second year, seemingly a consequence of better hunting skills, greater familiarity with preferred foraging ranges, and reduced energy expenditures during migration. In contrast, Harmata et al. (2001) found 95% of ferruginous hawks banded in Montana were dead at 1.5 years, and that mortality was highest among immature hawks compared to juveniles and adults, from the period between post-fledging dependence and sexual maturity.

Based on the documented movements, infrequent reports of ferruginous hawks sighted in the Rocky Mountains of British Columbia or Alberta (Grantmyre unknown, Decker 1970) are likely juveniles or breeders from Pacific states passing to interior grasslands. Extensive fall use of aspen parkland in the front range by adult hawk 15226 was unexpected and unusual for this species (Schmutz et al. 1980), although the nesting range of the species formerly extended to this area before the invasion of aspen into grassland (Schmutz et al. 1980). No ferruginous hawks have been sighted in Banff National Park since 1974 (H. Dempsey, pers. comm.).

Migration of juvenile ferruginous hawks provided insight into how migration pathways are established by the time hawks reach adulthood. Siblings and adults at the same nests migrated independently, and most related adults and juveniles used dissimilar migration patterns, suggesting innate orientation was not an influence on where most hawks moved. Rather, extensive movements during the first fall among large geographic regions showed exploration and learning were probably important in establishing the migration patterns that adults followed closely, if not precisely, during subsequent migrations. This resulted in a high degree of winter range philopatry of adults, also noted previously for ferruginous hawks in Colorado (Plumpton and Andersen 1998). Further, movements of 2 individuals to winter ranges as immatures averaged over 2000 kilometers less than they moved as juveniles to the same winter ranges. During their nearly continual wanderings in fall, juveniles may follow other ferruginous hawks to fall and winter prey concentrations. This is supported by my observations of several hawks feeding communally or sharing ground squirrel carcasses on fall ranges, similar to observations noted for wintering ferruginous hawks in prairie dog towns (Allison et al. 1995). Based on band recoveries of hawks from Alberta, Schmutz and Fyfe (1987) suggested hunting behavior and morphology predisposed ferruginous hawks to search out and winter in the same habitat types (grassland vs. desert) and feed on the same respective prey (small mammals vs. Lagomorphs) as they do on breeding areas. This hypothesis is difficult to apply to Washington's hawks, which nest in shrubsteppe habitats and might be expected to migrate in large numbers to the Great Basin desert to feed on Lagomorphs or groundsquirrels. However, jackrabbits and groundsquirrels are now uncommon and infrequently eaten as prey by Washington's ferruginous hawks (Richardson et al. 2001), and hawks apparently have adapted by eating a wider variety of prey species among many geographic areas. Additional evidence that learning was important to migration orientation was that neither juvenile nor adult cohorts of marked ferruginous hawks made consistent use of traditional migration corridors across the mountains (i.e., they showed broad-fronted migration). Not surprisingly, ferruginous hawks are infrequently recorded at hawk migration sites in Washington (pers. obs.) and considerably less than other species at sites elsewhere in western North America (Hoffman and Smith 2003). Broad-fronted migration of this species makes use of migration counts difficult to interpret for use in monitoring ferruginous hawk population trends (Hoffman and Smith 2003).

Based on the lack of nomadism, high adult fidelity to breeding sites, the identification of breeding adults previously banded as juveniles, and movement of immature birds back through the Pacific Northwest (including Washington), the breeding population of ferruginous hawks in Washington appears capable of sustaining itself assuming conditions in Washington are favorable to reproduction. I found no evidence to suggest this breeding population at the northern extent of the range is a population sink maintained by immigration from more productive source populations. Ideally, monitoring of juveniles to adulthood (2-yr-old; Bechard and Schmutz 1995) would provide information into what regional population the juveniles are recruited, but maximum duration of satellite PTTs did not allow tracking of juveniles to breeding age. The nesting population of ferruginous hawks in Washington has declined since 1996 in the drought-stricken Columbia Basin where hawks were captured for telemetry in this study (WRDS). Yet, all adult telemetered hawks that survived returned consistently to nesting territories, in some cases continuing to occupy territories even when mates failed to return. Breeding philopatry has been noted in other ferruginous hawk populations (Harmata 1981, Schueck et al. 1998), but in others nomadism has been suggested as a possible explanation for why certain breeding territories of ferruginous hawks are irregularly active (Woffinden and Murphy 1989). Evidence in Washington suggests hawks continue to return to breeding territories even to drought-effected habitats. Based on survival rates observed for telemetered hawks, only 4 of 10 adult hawks would be alive to reoccupy breeding areas every 4th year. If these breeding areas are in marginal habitats (e.g., habitats with low prey levels), they might be unattractive to prospective mates, resulting in greater numbers of unpaired individuals occupying territories (observed in this study), eventual death of both adults, fewer young returning to the region to nest, and territory attrition. Widespread territory attrition could result in regional extirpation in just a few years until drought conditions were alleviated and prey populations recovered, at least in areas without habitat alterations from such factors as residential development and agricultural conversion. The presence of few non-breeding adults and immature ferruginous hawks in Washington during the breeding season (pers. obs.) supports evidence of this type of population decline in the Columbia Basin of Washington.

MANAGEMENT IMPLICATIONS

Relevance of the non-breeding portion of the annual cycle of migratory raptors to population status may be under-emphasized because of the challenges of long-range monitoring to assess such factors as habitat and prey use. Satellite telemetry allowed the determination that ferruginous hawks spent 49% of the year was spent away from Washington, they migrated broadly throughout much of the known range of the species, and experienced survival similar to rates from a limited number of other studies where populations are apparently stable (e.g., Montana, North Dakota, Alberta) or declining (e.g., Utah, Saskatchewan) (Olendorff 1993). Assuring survival of the adult, immature, and to a lesser degree the juvenile age class bears importantly on the status of Washington's hawk population, because stability of raptor populations is most dependent on maintaining an adequate ratio of floating to breeding adults (Hunt 1998). Proper interpretation of population parameters during relatively short-term, cyclic population declines due to temporary factors such as drought (e.g., Washington presently, Utah and Colorado; Woffinden and Murphy 1989, Olendorff 1993) is challenging in the context of larger, permanent population declines due to direct or indirect mortality sources. Direct mortality from human factors during winter does not appear unusually high for Washington's hawks, although I was unable to confirm the fate of all hawks. In California, hawks wintered near windfarms, and almond orchards (M. Smith, pers. comm.), both potential sources of ferruginous hawk mortality (in the latter case due to use of organophosphate dormant sprays; Hooper et al. 1989, Hosea 1996). Although only 1 Washington hawk wintered in Mexico, electrocution remains an important direct mortality source for migrant hawks wintering there (Cartron et al. 2000, Bak et al. 2001). More insidious is the potential for compromised health and survival of wintering hawks from indirect mortality sources such as increased agricultural conversion and invasion of grasslands by shrubs and trees that are removing ground squirrel populations in Alberta (Schmutz 1987) and Saskatchewan (Houston and Bechard 1984), and rapid urbanization and agricultural conversion of traditional winter ranges in the central California valley and front range of Colorado that are eliminating prairie dog and ground squirrel colonies (M. Smith pers. comm., Plumpton and Andersen 1998). Because ferruginous hawk populations using these traditional winter areas are a composite of several breeding populations, the strength of managing for their protection lies in inter-state and international communication and cooperation that details a more complete picture of the breeding populations potentially impacted by the changes affecting them, and evaluates the metapopulation status of the species. Current satellite telemetry studies throughout the species range are expected to provide some of these details (unpubl. data, M. Fuller pers. comm.).

Acknowledgements: The Woodland Park Zoo was a critical partner in success of this project. In addition to providing financial support, the WPZ Raptor Staff including T. Aversa, B. Barker, S. Manetti, G. Albrecht, and E. Rose contributed field assistance during trapping. The U.S. Fish and Wildlife Service (Partnerships for Wildlife) in cooperation with the Wildlife Program, and Cooperative Volunteer Program of the Washington Department of Fish and Wildlife (WDFW) provided primary financial support. Battelle Pacific Northwest National Laboratories provided critical logistical help, coordinated by B. Tiller. B. Davies, M. Horowitz, and J. Liguori provided trapping assistance. I thank G. Kuiper and G. Schmidt for coordinating the school project with the Grand Coulee Dam School District, and personnel of the Priest Rapids Hatchery for accommodations. The Woodland Park Zoo and Sarvey Wildlife Center provided great horned owls for use as lure birds. Long-distance monitoring of hawks could not have been accomplished without the assistance of several dedicated biologists and game agents. I especially thank J. Linthicum, M. Smith, J. Pagel, C. Gill, G. Hunt, H. Peters, and other associates of the Santa Cruz Predatory Bird Research Group; R. Stafford, D. Walker, and T. Young of the California Fish and Game Department; S. Fitton of the Bureau of Land Management; M. Glines of Montana Fish, Wildlife, and Parks; M. Crocker of the Oklahoma Fish and Game Department; S. Findholt Oregon Department of Fish, Wildlife and Parks; and Canadian biologists J. Schmutz, S. Houston, U. Banasch, and J. Allen. A. Leary, P. Bartels, M. Fuller, J. Stofel, L. Schueck, and E. Yensen provided technical assistance, and M. Vander Haegen reviewed a draft of this report.

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Appendix A.

Table 1. Comparative body measurements of adult male and female ferruginous hawks captured in southcentral Washington, 1999–2002 (± SD).

Characteristic	Female	*n*	Male	*n*	t	*p*
weight (g)	1587 (36)	5	1057 (26)	8	12.19	<0.0001
wing chord (mm)	455 (7)	5	430 (4)	8	3.74	0.003
hallux (mm)	33.5 (0.3)	5	26.5 (0.9)	8	6.15	<0.0001
beak depth (mm)	23.7 (0.9)	6	18.3 (0.2)	6	5.69	<0.0001
wingspread (mm)	1295 (70)	4	1178 (33)	3	1.35	0.236

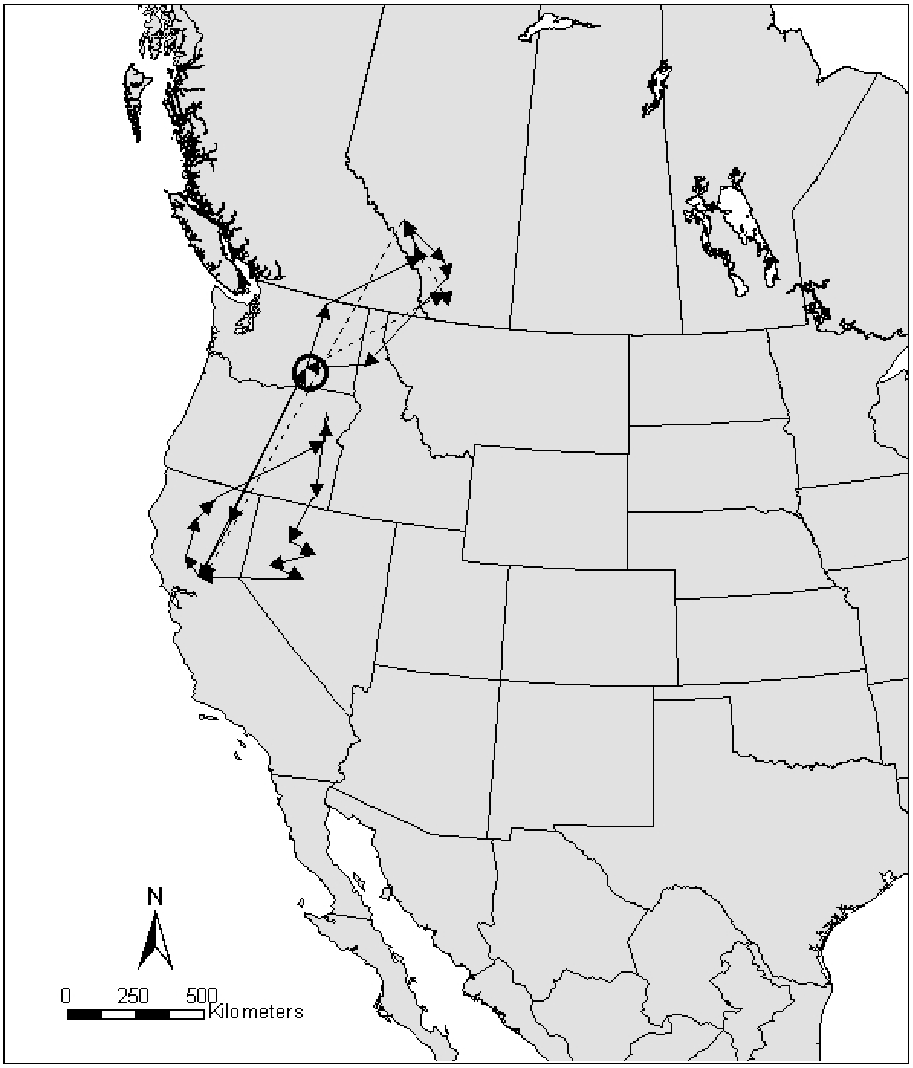
Table 2. Capture histories and measurements of ferruginous hawks in southcentral Washington, 1999–2002.

Date	Territory	Occno.	Age	Sex	PTT ID	USGS	Weight (g)	Wing Chord (mm)	Hallux Length(mm)	Beak Depth (mm)
5/27/99	Route 2	273	A	M	15226	877-62665	978	430	24.6	n/a
5/29/99	WPPSS	132	A	F	15227	1207-25044	1670	450	33.2	24.0
5/30/99	Webber Canyon	15	A	F	15185	608-41259	1654	453	33.8	22.4
6/2/99	May Junction	184	A	F	15184	1207-35127	1480	450	34.0	23.6
6/3/99	Beck 1	285	A	F	15216	608-41260	1532	480	34.1	22.5
6/4/99	FFTFN	135	A	M	15218	877-62667	1026	423	31.7	19.4
6/7/99	Chandler Butte	64	A	M	15217	877-62668	1220	450	25.5	18.3
6/11/99	Pipeline East	162	J	F	n/a	608-41263	n/a	n/a	n/a	n/a
6/11/99	Pipeline East	162	J	M	n/a	877-62666	n/a	n/a	n/a	n/a
6/12/99	Sulfur Lake East	194	A	M	15186	877-62669	1040	420	27.0	18.5
6/14/99	Kahlotus West	129	A	M	15228	877-62670	1042	418	25.5	18.1
6/14/99	Webber Canyon	301	J	F	10372	608-41265	1348	310	29.0	21.0
6/14/99	Webber Canyon	301	J	F	n/a	608-41262	n/a	n/a	n/a	n/a
6/14/99	Webber Canyon	301	J	F	n/a	608-41264	n/a	n/a	n/a	n/a
6/14/99	Webber Canyon	301	J	M	n/a	877-62671	n/a	n/a	n/a	n/a
5/26/00	WPPSS	132	A	M	15185b	877-62672	1010	436	28.1	18.0
5/30/00	FFTF Jeep	188	A	F	16652	608-41266	1600	442	32.4	22.0
6/2/00	Pipeline East	162	A	M	10394	877-62673	1049	432	25.5	18.0
6/22/00	Pipeline East	162	J	M	10379	877-62674	922	n/a	22.2	17.0
6/19/01	Horn Rapids	185	J	F	15227b	608-41268	1268	350	27.5	18.5
6/19/01	Horn Rapids	185	J	F	15226b	608-41213	1432	392	30.0	20.5
6/19/01	Dune	199	J	F	15186b	608-41214	1318	340	28.0	20.5
6/27/01	Horn Rapids	185	J	M	n/a	877-62676	1168	370	26.5	20.0
7/2/01	WPPSS	132	J	F	15227c	608-41215	1230	320	29.5	20.5
7/16/01	May Junction	184	J	F	15218b	608-41267	1470	335	27.0	20.5
6/5/02	Juniper Dunes	87-5	A	F	n/a	608-41216	n/a	n/a	n/a	28.1
6/5/02	Juniper Dunes	87-5	A	M	15184b	877-62677	1094	425	n/a	24.2
6/11/02	FFTFN	135	J	M	15217b	877-62679	1082	308	24.1	22.0
6/11/02	Horn Rapids	185	J	F	15216b	608-41219	1444	345	30.0	27.3
6/12/02	Juniper Dunes	87-5	J	F	15185c	608-41218	1548	335	28.6	25.7
6/18/02	Dune	199	J	M	10372b	877-62682	1038	311	24.4	22.4
6/24/02	Juniper Dunes	87-3	J	F	15218c	608-41222	1488	350	28.5	27.0
6/24/02	Juniper Dunes	87-3	J	F	n/a	608-41220	1434	308	28.5	25.5
6/24/02	West Aspect	13	J	F	15227d	608-41224	1192	324	28.0	26.9
6/24/02	West Aspect	13	J	F	n/a	608-41223	1198	330	29.0	21.3
6/24/02	West Aspect	13	J	F	n/a	608-41221	1134	310	28.5	25.5
6/27/02	Dark Phase	133	J	F	16652b	608-41225	1532	307	28.5	25.0
7/3/02	May Junction	184	J	F	15217c	608-41226	1564	350	28.5	25.5

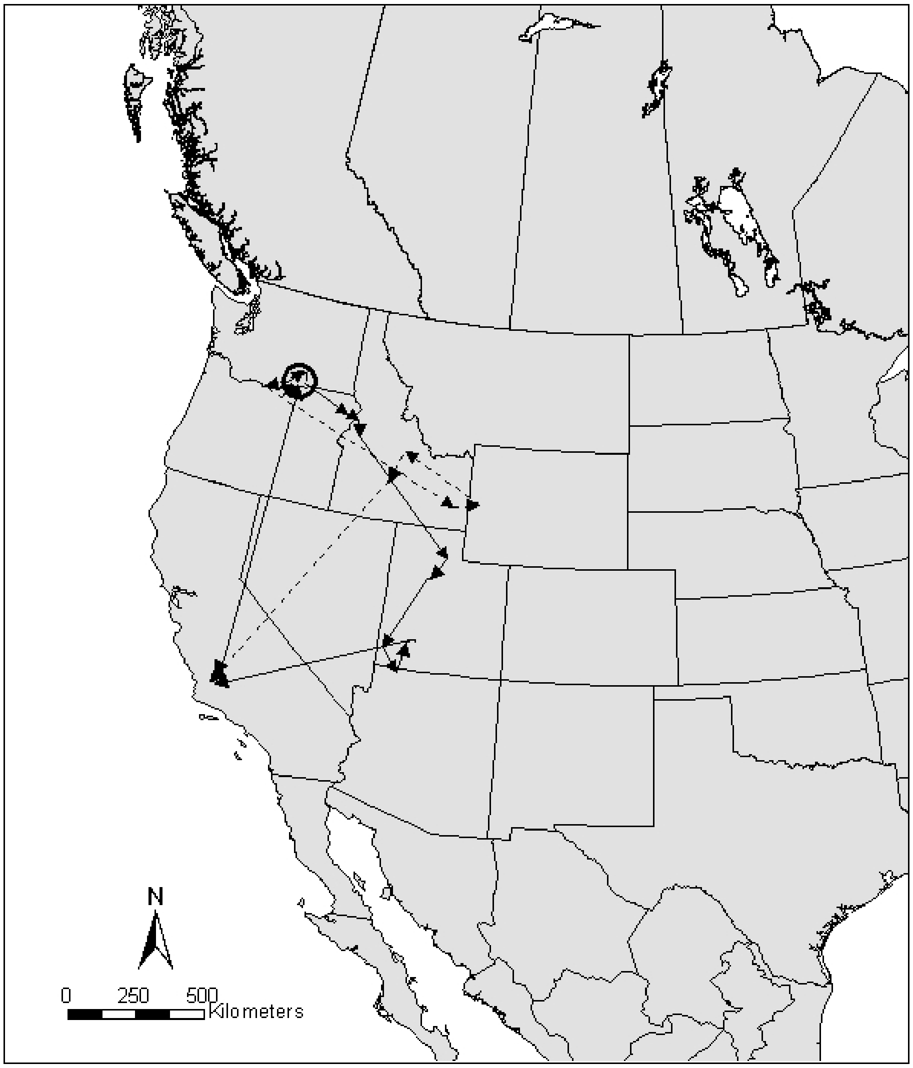
Table 3. Monitoring history of telemetered ferruginous hawks captured in southcentral Washington, 1999–2003.

PTT ID	Date deployed information	Last date with location	Last date with activity information	No. days monitored	No. locations by class[a]							Total *n*
					3	2	1	0	A	B	Z	
15226	5/27/99	10/19/00	10/19/00	510	8	30	100	188	78	85	183	672
15227	5/29/99	12/25/99	12/25/99	210	4	8	39	81	34	34	43	243
15185	5/30/99	11/15/99	11/15/99	169	8	13	41	79	28	32	44	245
15184	6/2/99	9/24/00	6/5/01	733	1	3	7	35	46	56	182	330
15216	6/3/99	6/6/00	6/6/00	368	5	14	42	98	89	76	126	450
15218	6/4/99	11/9/00	11/17/00	531	8	28	84	256	75	79	180	711
15217	6/7/99	8/24/99	8/24/99	78	3	9	24	85	26	23	57	227
15186	6/12/99	11/14/00	02/12/01	610	8	15	83	179	88	101	175	649
15228	6/14/99	8/4/01	12/19/01	553	6	20	62	152	83	111	162	596
10372	6/14/99	6/16/01	7/28/01	772	9	9	32	82	31	66	125	354
15185b	05/26/00	10/08/00	11/04/01	527	0	7	19	47	24	14	15	126
16652	5/30/00	12/7/00	12/7/00	191	9	28	71	271	52	80	152	663
10394	6/2/00	7/13/01	7/16/01	409	9	11	72	349	106	145	319	1011
10379	6/22/00	8/01/00	8/1/00	40	0	6	12	2	4	9	4	37
15227b	6/19/01	6/20/01	6/20/01	2	0	0	0	3	0	1	3	7
15226b	6/19/01	7/14/02	7/14/02	390	11	40	91	215	67	72	118	614
15186b	6/19/01	7/14/01	12/19/01	183	1	0	3	12	6	4	17	43
15227c	7/2/01	8/8/01	8/8/01	37	1	10	20	49	10	20	63	173
15218b	7/23/01	9/11/011	10/1/01	40	4	8	19	66	24	20	30	171
15184b	6/4/02	07/14/03	7/14/03[b]	405	5	18	65	105	46	71	56	366
15217b	6/11/02	6/26/02	6/26/02	15	0	0	2	7	3	5	7	24
15216b	6/11/02	5/31/03	7/9/03[b]	401	3	4	29	83	32	49	25	196
15185c	6/12/02	11/09/02	11/09/02	150	0	2	7	27	14	19	13	82
10372b	6/18/02	7/20/02	7/20/02	32	0	2	9	24	7	14	19	75
15218c	6/24/02	5/16/03	6/25/03[b]	382	0	4	35	54	33	35	33	194
15227d	6/24/02	7/12/02	7/12/02	18	0	0	0	3	0	0	2	5
16652b	6/26/02	7/28/02	11/05/02	132	1	6	24	29	6	11	24	101
15217c	7/5/02	8/17/02	8/17/02	43	2	0	2	4	4	4	8	24
			Total	7931	106	295	994	2585	1016	1236	2185	8387
			%		1	4	12	31	12	15	26	

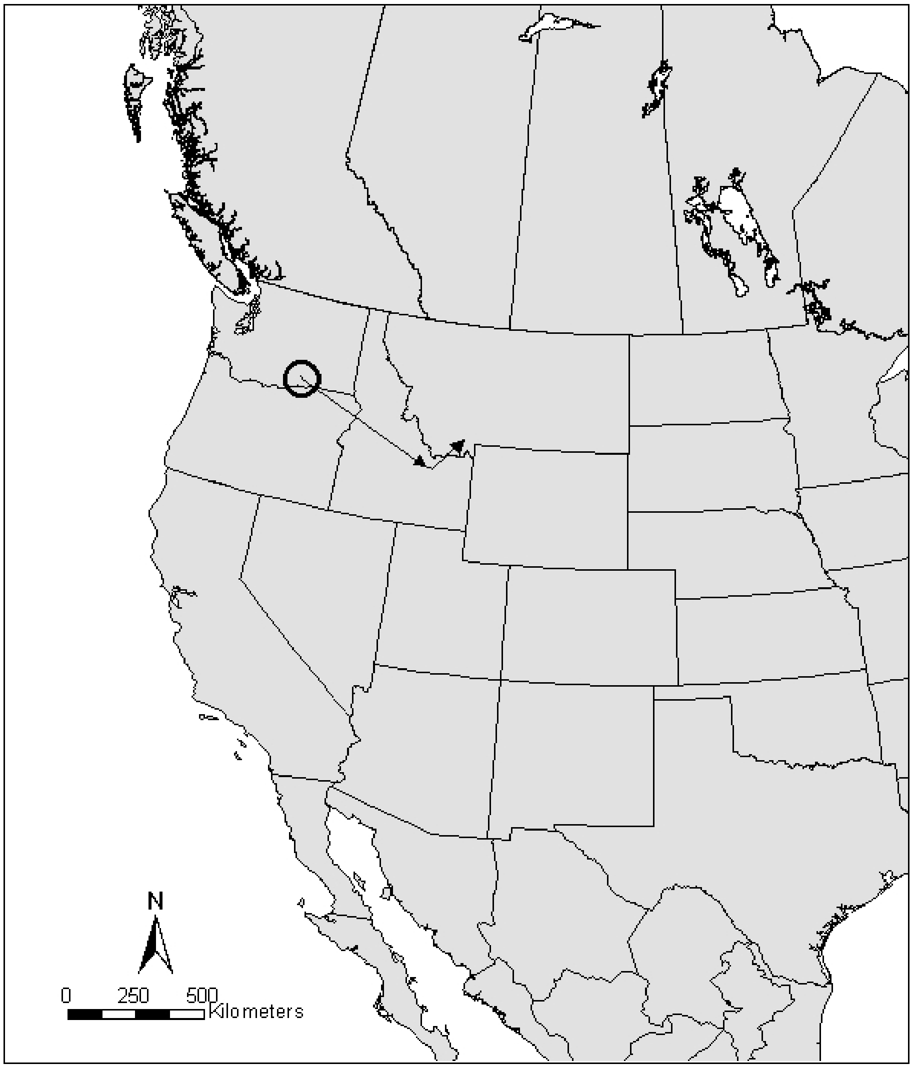
[a] Location quality assigned by ARGOS: class 3, accurate to <150m; class 2, accurate to <350m; class 1, accurate to <1000m; class 0, accurate to >1000m (i.e., no more accurate than 1000 m); class A, B, and Z no accuracy assigned.
[b] PTT still active when data were summarized.



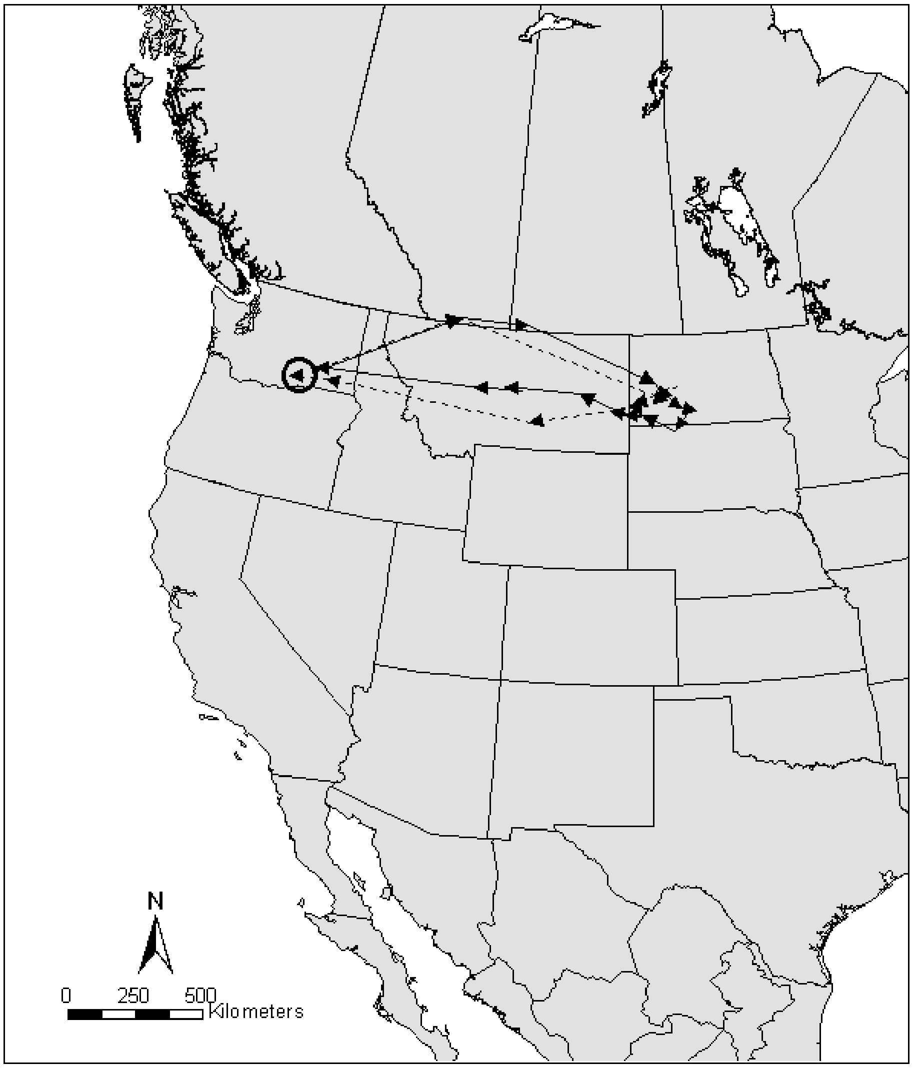
Appendix B. Fig. 1. Two annual migrations of adult male ferruginous hawk 15226 from his territory in south-central Washington (circle). Complete migration from 7/18/99 through 2/25/00 was 5,788 km (solid line). Migration from 6/26/00 through 10/19/00 was 2,481 km (dashed line). This hawk returned to breed in Washington in 2001. The estimated complete migration distance to Washington from central California, where the PTT expired in winter 2000, was a minimum of 3,358 km.



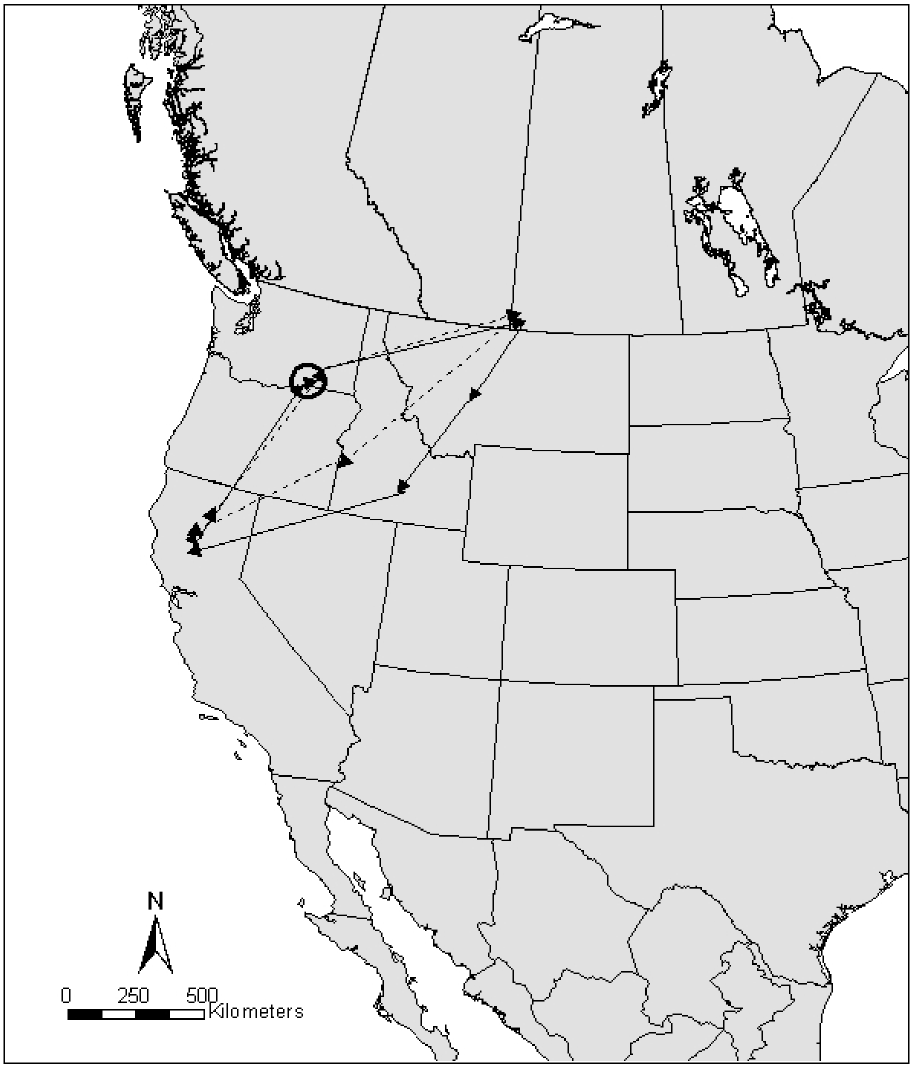
Appendix B. Fig. 2. Two annual migrations of adult male ferruginous hawk 15218 from his territory in south-central Washington (circle). Complete migration from 7/27/99 through 3/18/00 was 3,887 km (solid line). Migration from 7/15/00 through 11/17/00 was 2,625 km (dashed line). This hawk returned to breed in Washington in 2001. The estimated complete migration distance from central California, where the PTT expired in winter 2000, was a minimum of 3,870 km.



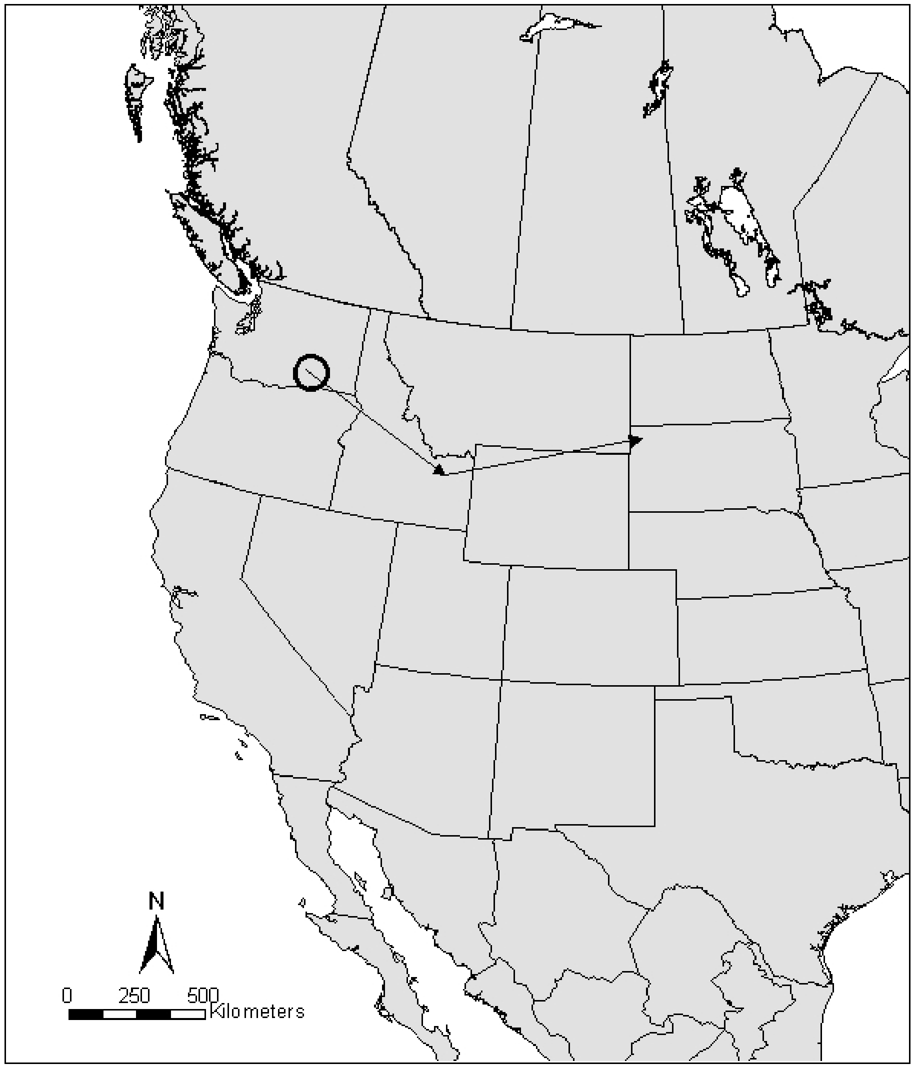
Appendix B. Fig. 3. Migration of adult male ferruginous hawk 15217 from his territory in south-central Washington (circle). Migration from 7/22/99 through 8/23/99 was 770 km (solid line).



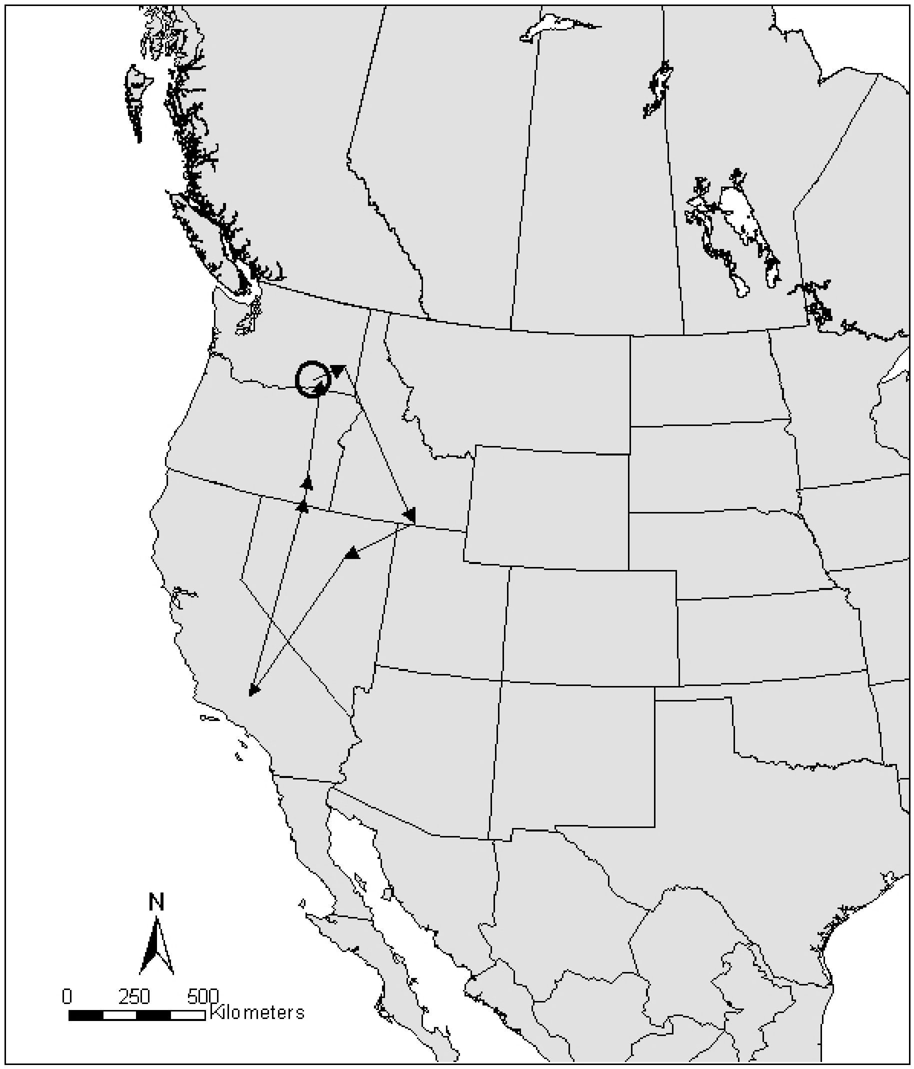
Appendix B. Fig. 4. Complete annual migrations of adult male ferruginous hawk 15186 from his territory in south-central Washington (circle). Migration from 7/12/99 through 11/19/99 was 3,271 km (solid line). Migration from 7/1/00 to 11/14/00 was 3,029 km (dashed line).



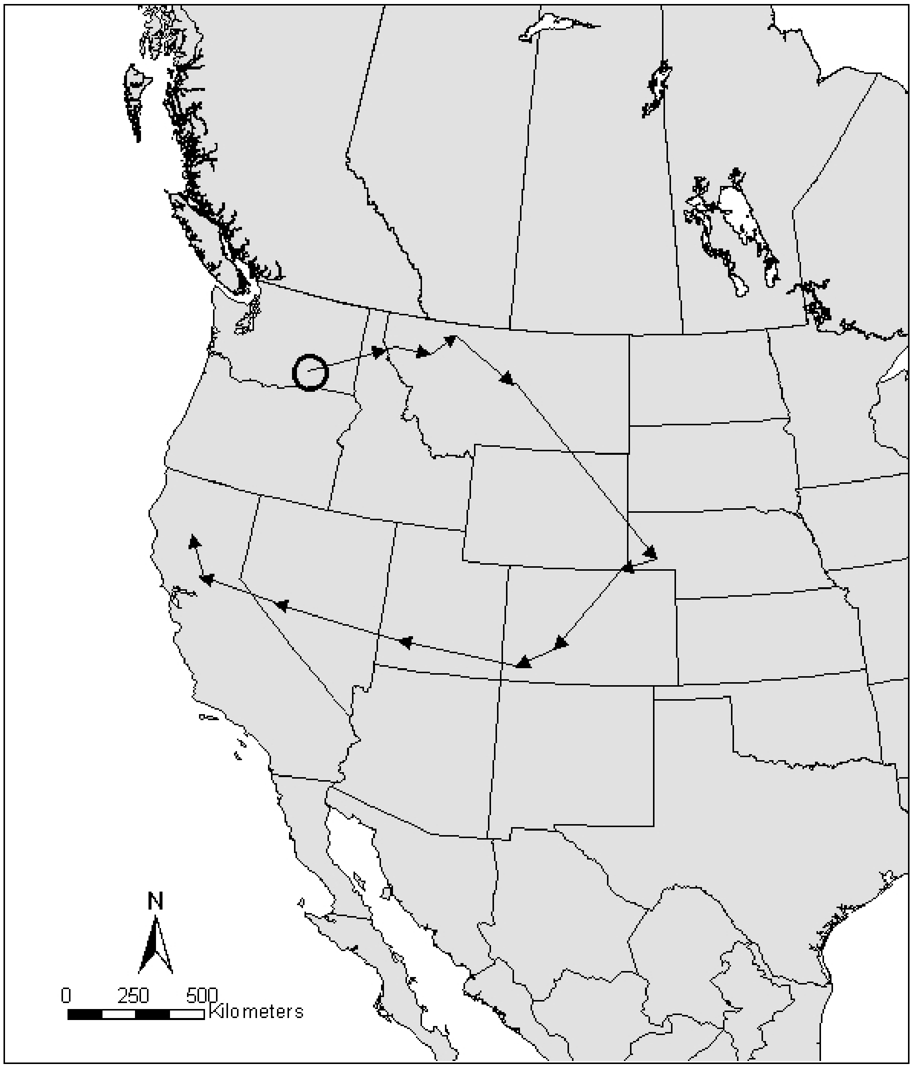
Appendix B. Fig. 5. Complete annual migrations of adult male ferruginous hawk 15228 from his territory in south-central Washington (circle). Migration from 7/15/99 through 3/13/00 was 3,282 km (solid line). Migration from 7/18/00 to 3/4/01 was 3,149 km (dashed line).



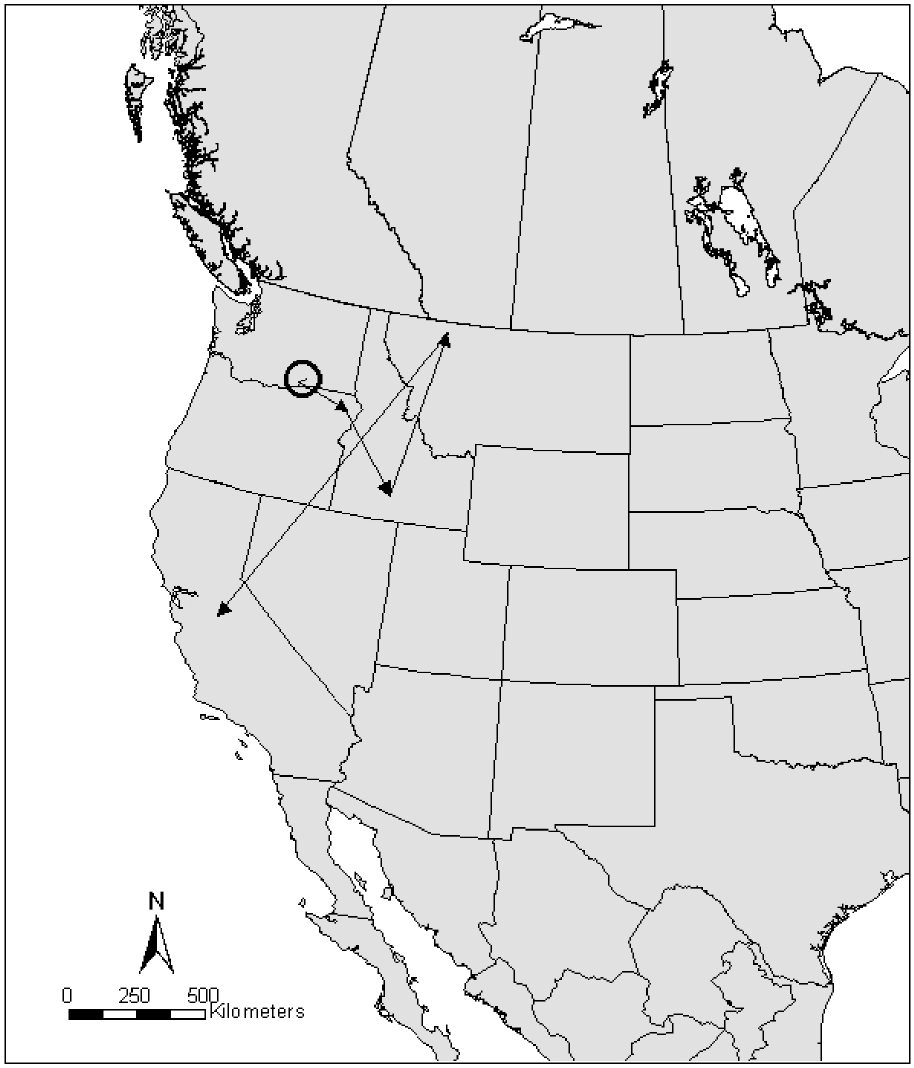
Appendix B. Fig. 6. Migration of adult male ferruginous hawk 15185b from his territory in south-central Washington (circle). Migration from 7/6/00 through 10/8/00 was 1,375 km (solid line).



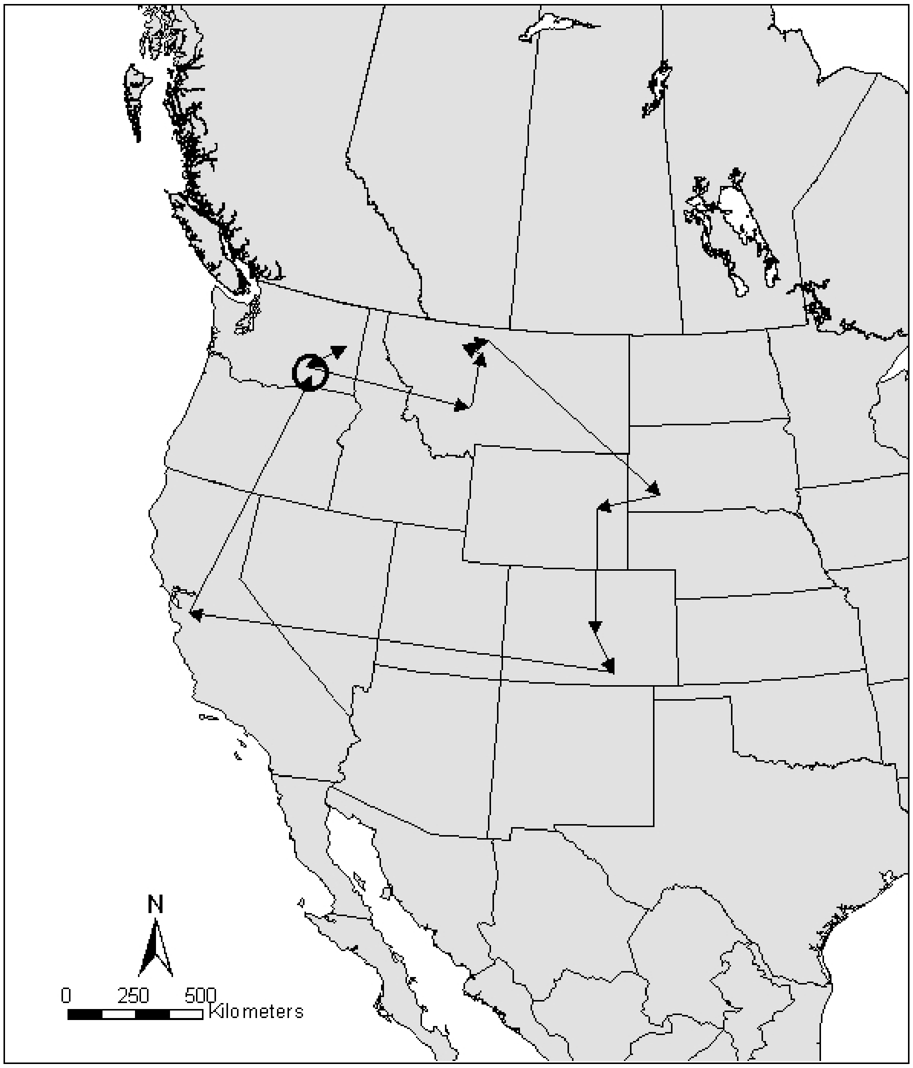
Appendix B. Fig. 7. Complete migration of adult male ferruginous hawk 10394 from his territory in south-central Washington (circle). Migration from 7/23/00 through 3/4/01 was 3,296 km (solid line).



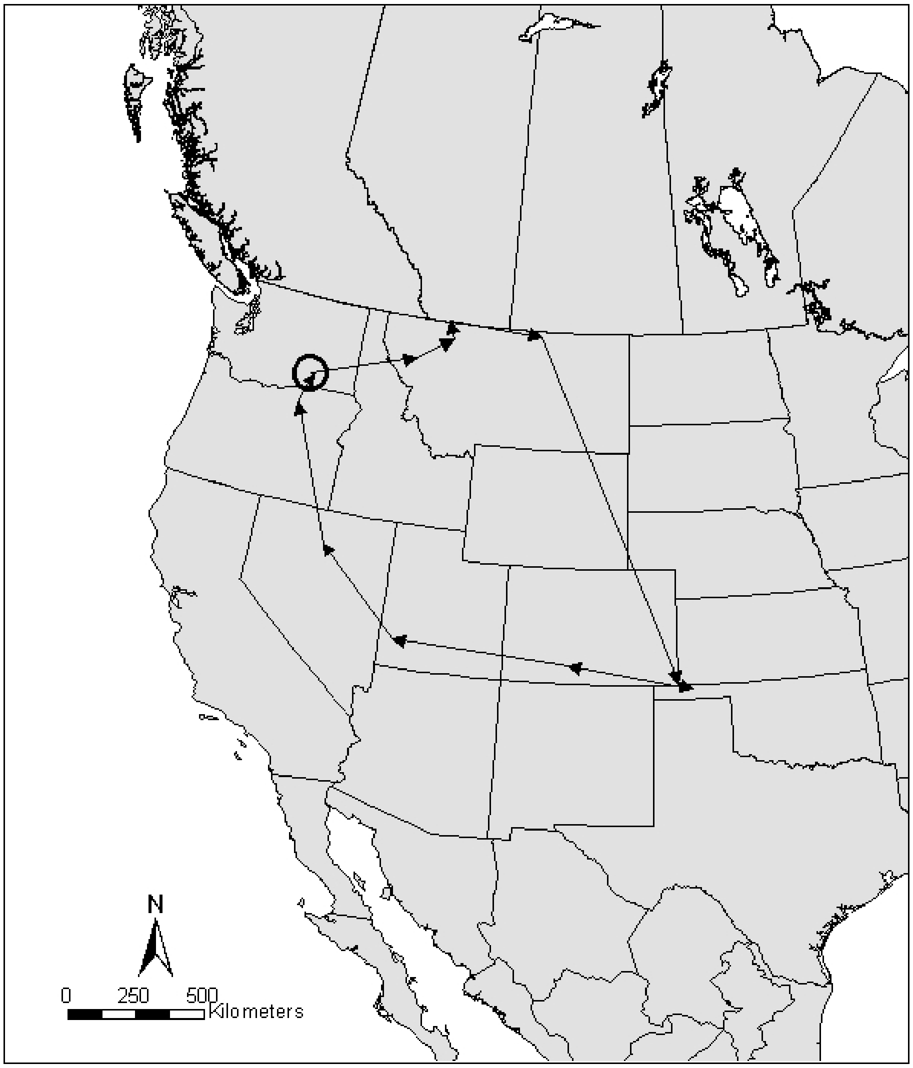
Appendix B. Fig. 8. Migration of adult female ferruginous hawk 15227 from her territory in south-central Washington (circle). Migration from 7/2/99 through 12/16/99 was 3,780 km (solid line). If this hawk had returned to her territory from northern California where she died, her complete migration would have been a minimum of 4,451 km.



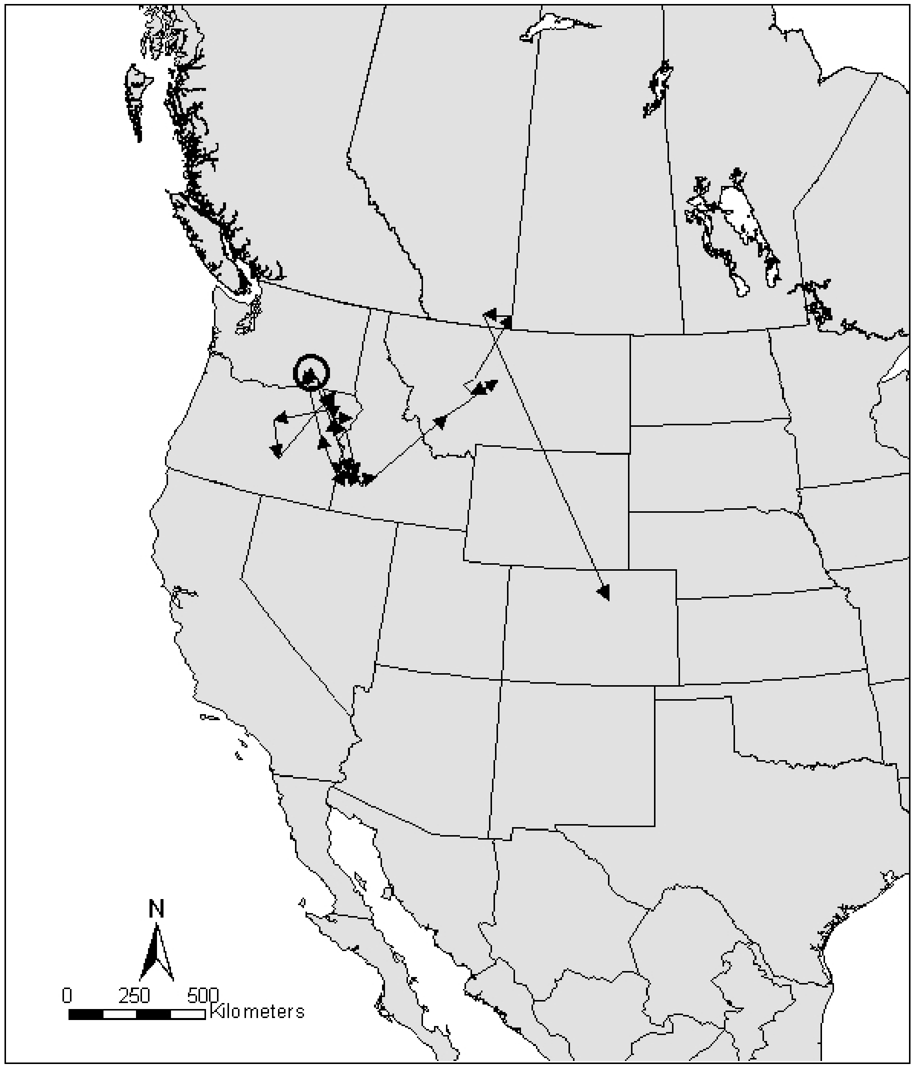
Appendix B. Fig. 9. Migration of adult female ferruginous hawk 15185 from her territory in south-central Washington (circle). Migration from 7/1/99 through 11/15/99 was 2,678 km (solid line). If this hawk had returned to her territory from central California where she died, her complete migration would have been a minimum of 3,646 km.



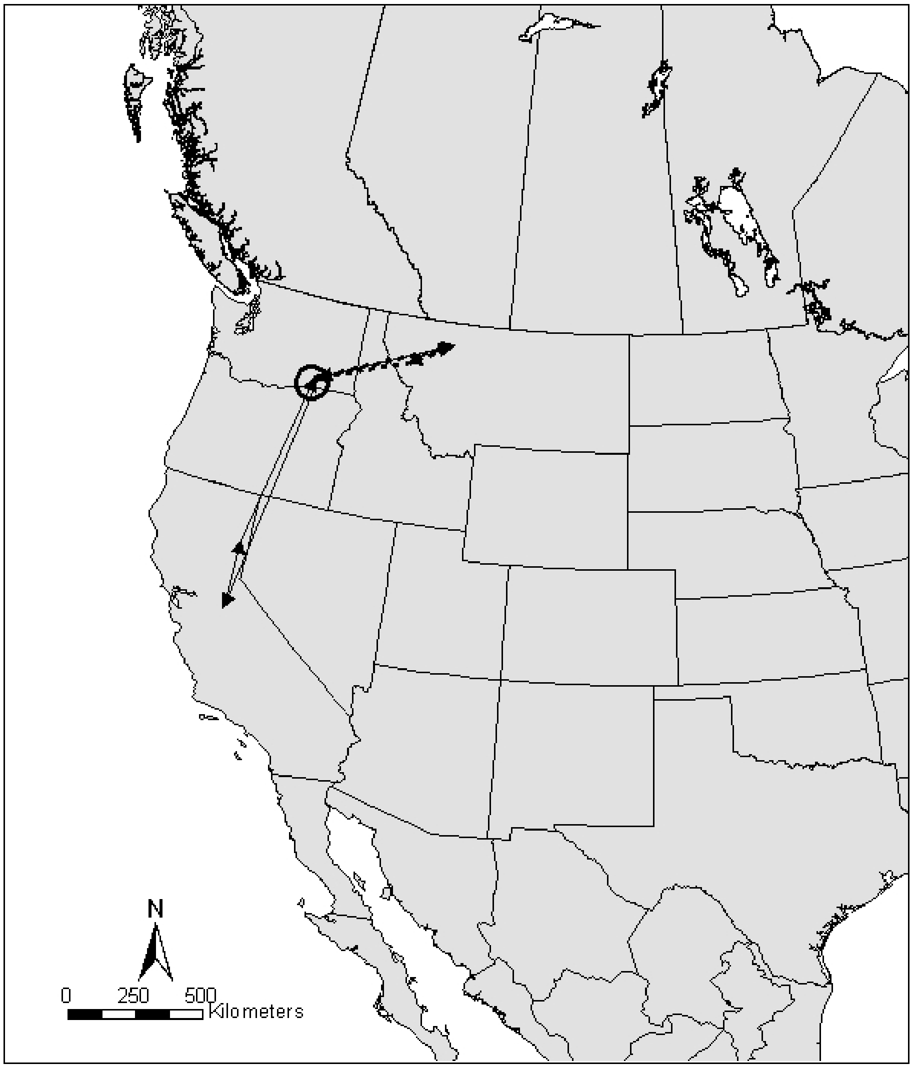
Appendix B. Fig. 10. Complete migration of adult female ferruginous hawk 15184 from her territory in south-central Washington (circle). From 6/29/99 through 3/10/00 this hawk migrated 5,788 km (solid line).



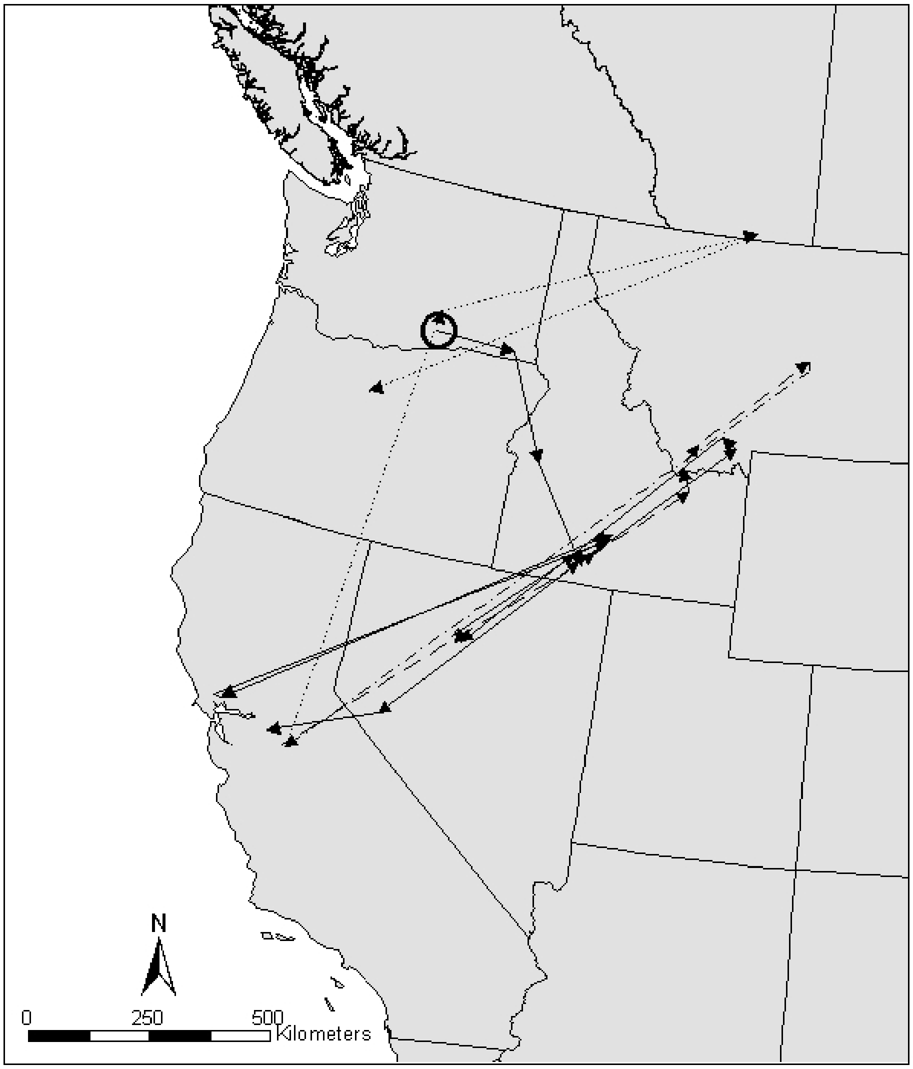
Appendix B. Fig. 11. Complete migration of adult female ferruginous hawk 15216 from her territory in south-central Washington (circle). From 7/2/99 through 3/10/00 this hawk migrated 4,722 km (solid line).



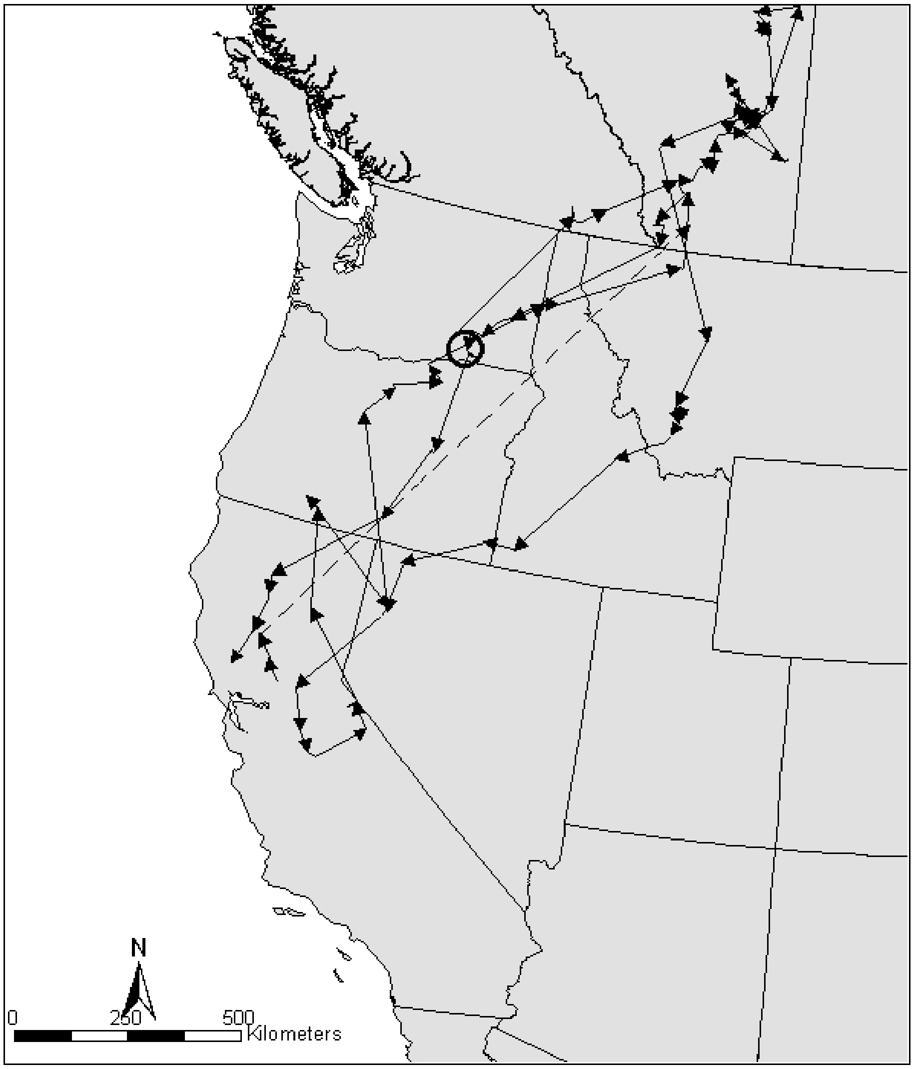
Appendix B. Fig. 12. Migration of adult female ferruginous hawk 16652 from her territory in south-central Washington (circle). From 6/16/00 through 12/7/00 this hawk migrated 4,997 km (solid line).



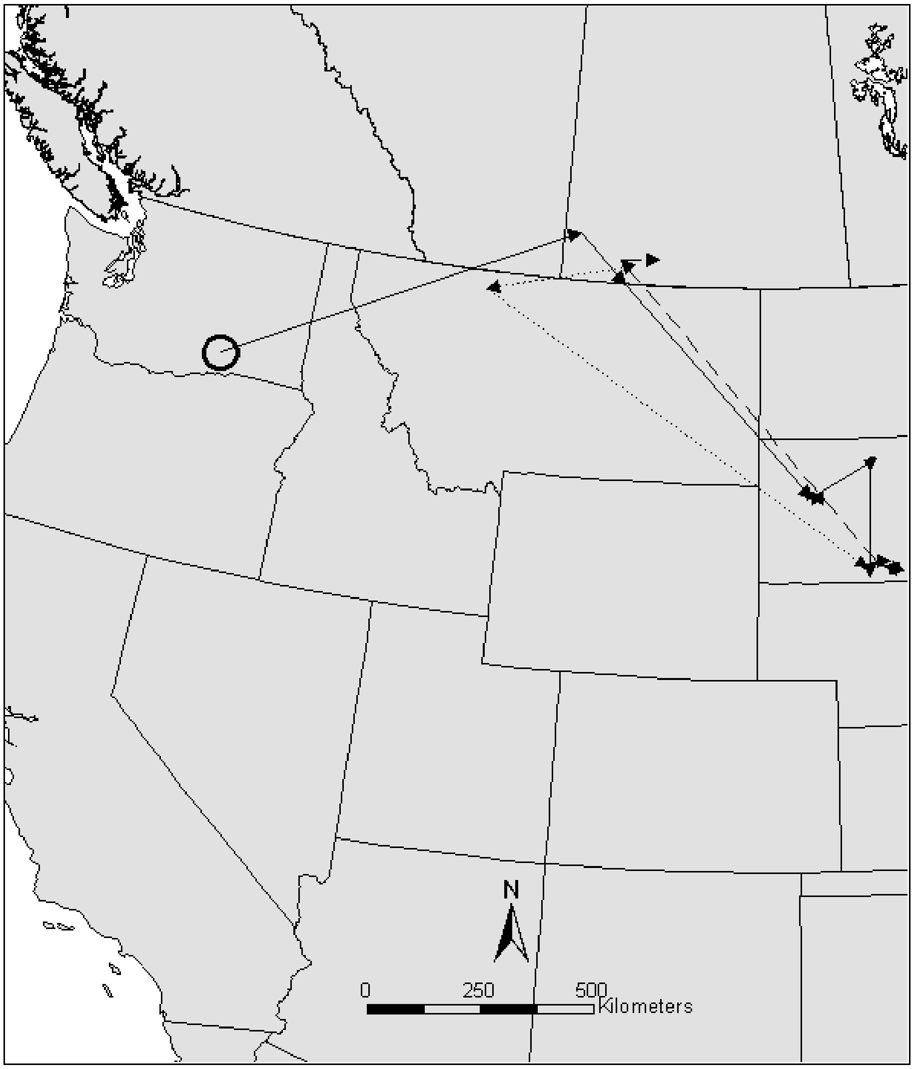
Appendix B. Fig. 13. Two annual migrations of adult male ferruginous hawk 15184b from his territory in south-central Washington (circle). From 7/23/02 through 3/4/03 this hawk migrated 2,918 km (solid line). The second migration began 7/9/03 and was in progress at the time these data were reported. Initial migration from the territory to Montana and return to the territory was identical to that in 2002 (dashed line).



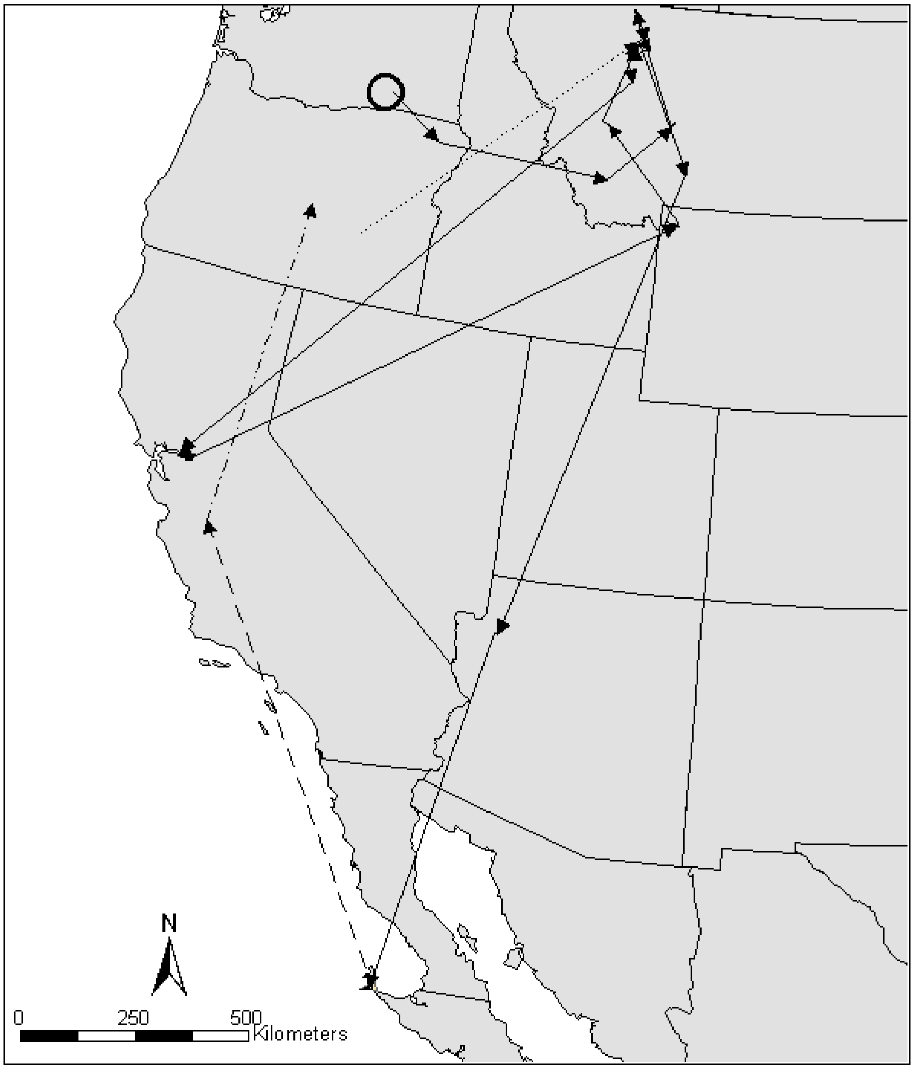
Appendix B. Fig. 14. Migration of juvenile female ferruginous hawk 10372 from her nest in south-central Washington (circle). Movements to the winter range in central California from 7/14/99 to 10/27/99 totaled 4,827 km (64 km/day) and included two excursions between the interior northwest and California (solid line). Movements from the winter range to the interior northwest between 4/9/00 and 9/20/00 totaled 1,425 km (dashed line), and the return migration to California from 9/28/00 to 10/7/00 totaled 1,344 km (dashed/dotted line). Movement from the winter range to the Pacific Northwest from 3/15/01 through 6/16/01 totaled 2,522 km and included a movement a few kilometers north of her natal territory (dotted line).



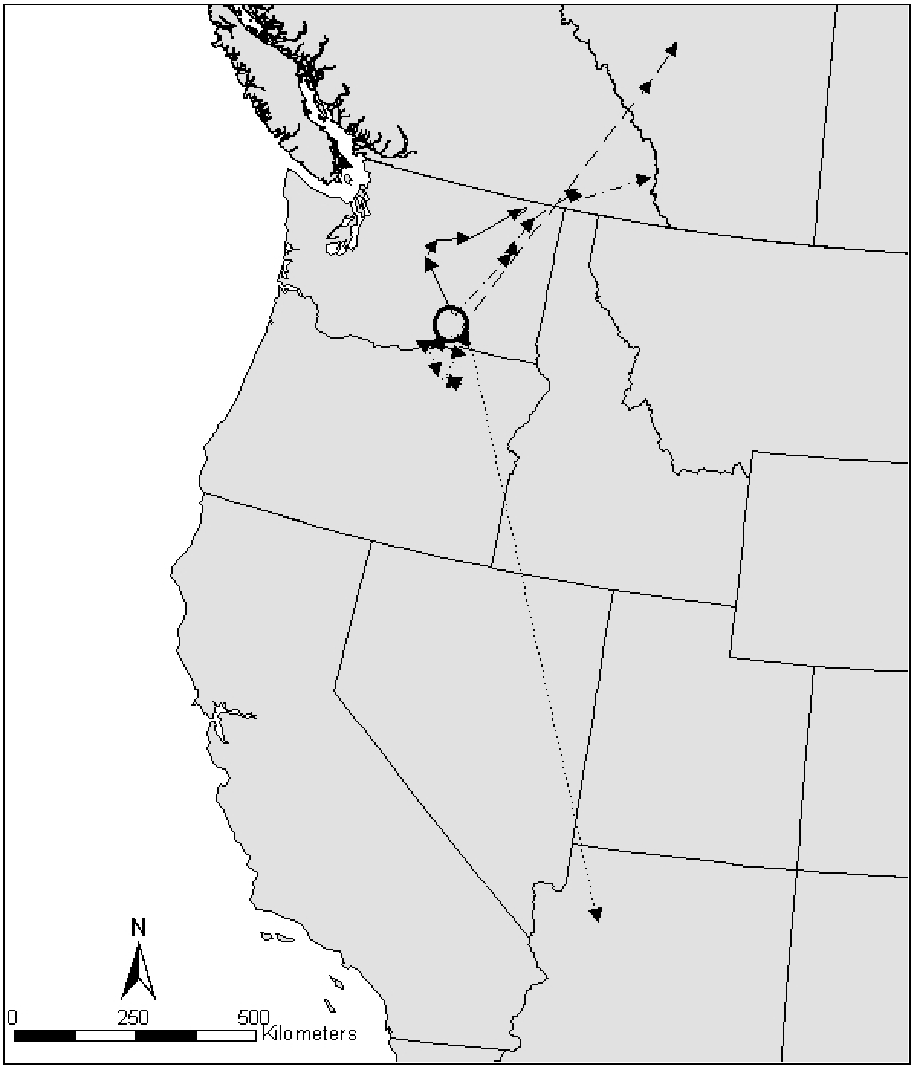
Appendix B. Fig. 15. Migration of juvenile female ferruginous hawk 15226b from her nest in south-central Washington (circle). Movements to the winter range in central California from 7/14/01 to 10/18/01 totaled 10,092 km (105 km/day) and included two excursions from interior Canada to California where she wintered (solid line). She passed within a few kilometers of her natal territory twice, to and from migration to Canada. Movement from the winter range to near Lethbridge, Canada, from 2/3/02 to 7/14/02, totaled 1,478 km (dashed line) .



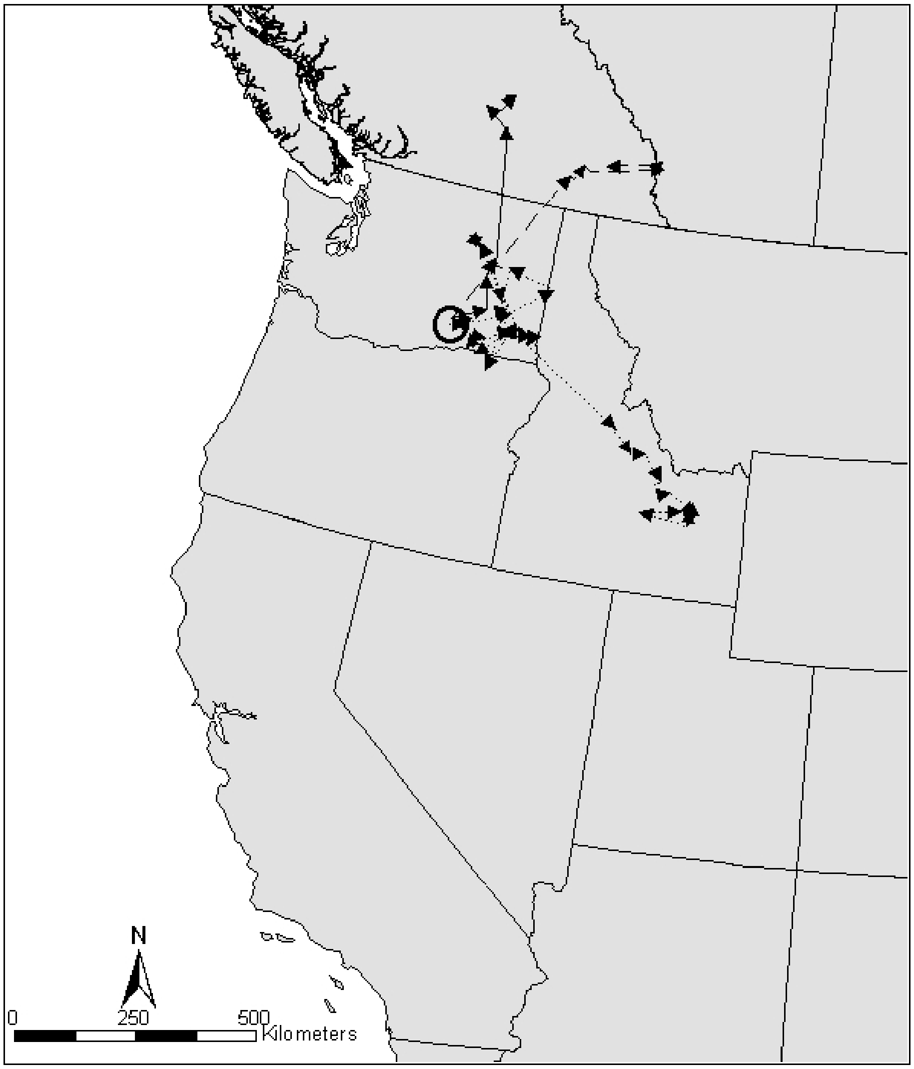
Appendix B. Fig. 16. Migration of juvenile female ferruginous hawk 15216b from her nest in south-central Washington (circle). Movement to the winter range in Nebraska from 7/17/02 to 10/6/02 totaled 2,690 km (solid line). Movement from the winter range to the Cypress Hills, Saskatchewan, from 5/1/03 to 5/8/03 totaled 1,278 km (dashed line). The return to Nebraska between 8/9/03 and 9/2/03 totaled 1,643 km (dotted line).



Appendix B. Fig. 17. Migration of juvenile female ferruginous hawk 15218c from her nest in south-central Washington (circle). Movement to the winter range on Baja California from 7/26/02 to 10/4/02 totaled 6,947 km (98 km/day) and included an excursion to California prior to moving south to the Baja Peninsula (solid line). This hawk wintered at the coastal tip of the Vizcaino Desert, Mexico, for at least 47 days through 11/30/02. She migrated 1,143 km to California during the winter, the actual route unknown but the shortest route shown here over the Pacific Ocean (dashed line). She moved 762 km to Oregon from 3/29/03 and 4/22/03 (dashed/dotted line). From 5/16/03 to 9/5/03 she moved 737 km to Montana (dotted line).



Appendix B. Fig. 18. Migration of four juvenile ferruginous hawks to fall ranges from their nests in south-central Washington (circle). Male hawks 10372b (solid line) and 10379 (dashed line) died less than 1 week after dispersing, and female 15185c (dotted line) died within 10 weeks after dispersing. Contact with female hawk 16652b (dashed/dotted lline) was lost less than one week after dispersal, and this hawk was a confirmed mortality near Lethbridge, Alberta by November.



Appendix B. Fig. 19. Migration of three juvenile, female ferruginous hawks to fall ranges from their nests in south-central Washington (circle). Hawk 15227c died within 1 week after dispersing (solid line). Hawk 15186b apparently experienced PTT failure 2 days after dispersing (dotted line). Satellite contact with hawk 15218b was lost less than 7 weeks after dispersal (dotted line). This hawk made two pre-dispersal movements to eastern Washington prior to moving into Idaho.

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