Home Range, Daily Movements and Site Fidelity of Male Reeves's Pheasants Syrmaticus reevesii in the Dabie Mountains, Central China

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Reeves's pheasant *Syrmaticus reevesii* is a threatened species endemic to China. During April 2000 - August 2003, we studied home range size, daily movements and site fidelity of 17 male Reeves's pheasants at Dongzhai National Nature Reserve in central China. Average annual home range size was 44.9 ± 24.6 ha (minimum convex polygon) and 23.8 ± 13.7 ha (95% fixed kernel estimation). The average annual core area determined by 60% fixed kernel estimator was 4.2 ± 3.5 ha. Home range size was generally smaller in winter than in spring, whereas the size of the core area remained stable through all seasons. Conifer-broadleaf mixed forests occupied a very large part of home ranges and core areas. Male pheasants exhibited strong site fidelity among seasons and years. Our results provide baseline data for habitat management, habitat restoration and reintroduction of the Reeves's pheasant.

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Seasonal differences in the use of space within an individual's home range, or in size, location and habitat composition of the home range may reflect changing habitat needs (Boyce 1979, Aebischer et al. 1993, Philips et al. 1998, Judas & Henry 1999). Therefore, information on seasonal variation in various aspects of a species' home range is important for understanding its biology and for establishing conservation strategies.

Reeves's pheasant *Syrmaticus reevesii* is a threatened species endemic to China (Cheng et al. 1978,

Cheng 1987). It inhabits broadleaf habitats dominated by oaks *Quercus* spp. in subtropical forests with a dense canopy and sparse undergrowth between 200 and 2600 m a.s.l (Xu et al. 1991, Wu et al. 1994). Historically, the species was widely distributed and relatively common in central China (Cheng et al. 1978), but the species has been extirpated from much of its historical range in China due to illegal hunting and habitat degradation and loss (Xu et al. 1991, 1995, MacKinnon et al. 1996, Zheng & Wang 1998). It is classified as a vulnerable species by the

IUCN's Red List (IUCN 2006) and a nationally second-class protected wildlife species in China (State Council 1988). Nature reserves and habitat restoration in its historic range are likely necessary to protect and perpetuate this species (Madge & McGowan 2002, Zhang et al. 2003). Considerable information is available on the species' habitat (Wu et al. 1994), and winter habitat use (Fang & Ding 1997, Sun et al. 2001, Sun et al. 2002, Xu et al. 2002, 2005, 2006, 2007), but our knowledge of home range (Sun et al. 2003, Xu et al. 2005), daily movement patterns and site fidelity of Reeves's pheasant is still limited and inconclusive (Wu 1979, Hu & Wang 1981, Fang & Ding 1997), creating difficulties in establishing scientific and effective conservation strategies for the species.

As a part of a larger project examining the habitat use and spatial distribution of the Reeves's pheasant for establishing effective habitat management and restoration strategies, we examined home range, daily movement and their seasonal variations using radio-telemetry. Our main objectives were to: 1) estimate home range size, 2) quantify daily movements, 3) investigate seasonal variations in size of home ranges, and 4) examine home range fidelity among seasons and years.

Methods

Study site

We selected a study site in Dongzhai National Nature Reserve (31°40'N, 114°24'E), a former forest farm located on the northern slopes of the Dabie Mountain range in Henan Province of central China (Fig. 1) as this area comprises the major portion of the existing eastern distribution of Reeves's pheasant in China (Zheng & Wang 1998, Xu et al. 2007). The reserve is located in the northern subtropical zone where natural vegetation is characterised by mature forests dominated by oaks, masson pine *Pinus massoniana*, dyetree *Platycarya strobilacea,* beautiful sweetgum *Liquidambar formosana,* and Hupeh rosewood *Dalbergia hupeana*. Mature coniferous plantations dominated by Chinese fir *Cunninghamia lanceolata,* shrubby areas dominated by young oaks, young Chinese firs and glaucous allspice *Lindera glauca,* tea *Camellia* spp. gardens, and young plantations of Chinese fir occur in our study area.

Because Reeves's pheasants are concentrated mainly in the core areas of this reserve (Song &

Qu 1996, Xu et al. 2006, 2007), we selected a 400 ha part of the core area at Baiyun as our study area (see Fig. 1). Elevations at the site range from 100 m to 446 m a.s.l., and the climate is warm and humid, with a mean annual temperature of 15.1 (range: 13.2-40.1) and a mean annual precipitation of 1,209 mm. Habitat types within our study area (see Fig. 1) included conifer-broadleaf mixed forests (50%), broadleaf forests (14%), Masson pine forests (6%), planted Chinese fir forests (16%), young fir forests (6%), shrubs (8%) and farmland (1%) (Xu et al. 2007).

Capture and radio-tracking

We used about 30 foot-hold traps placed around a decoy to capture male Reeves's pheasants in April and May during 2000-2002 (Sun et al. 2003). On average, we trapped for about 20 days each year with at least 10 attempts on each trapping day. Each captured bird was fitted with a coloured plastic leg band and a necklace radio-transmitter (Biotrack Ltd, UK) with frequencies between 216.00 and 217.00 MHz. Transmitter mass (16 grams) was <2% of average pheasant body mass ($1,641.1 \pm 117.6$ grams, mean ± 1 SD, N = 17), and therefore likely had minimal effect on bird behaviour (Kenward 2001).

Radio-tagged pheasants were located using a portable TR-4 receiver and a Telonics hand-held three-element Yagi antenna. Bird locations were determined once or twice each day by triangulation from permanent reference points within a randomly selected 2-hour segment between 05:00 and 19:30 hours or by direct observation. In most instances (>95%), the distance from observer to pheasant was <200 m. To reduce telemetry errors, all azimuths were collected within a three minute period and triangulation angles were between 45° and 135° (Kenward 2001). The time between consecutive radio locations was on average 12 hours (range from about eight hours to 16 hours), normally resulting in two observations daily. Bird positions were then determined using a global positioning system (GPS, GARMIN 12XL).

To estimate telemetry error, we placed transmitters in our study site and recorded their location with GPS (GARMIN 12XL) and on a topography map. Then a naïve observer located these transmitters using the same triangulation procedure used for locating birds. The distance between these two locations for each transmitter was calculated as the telemetry error (Koehler & Pierce 2003). We
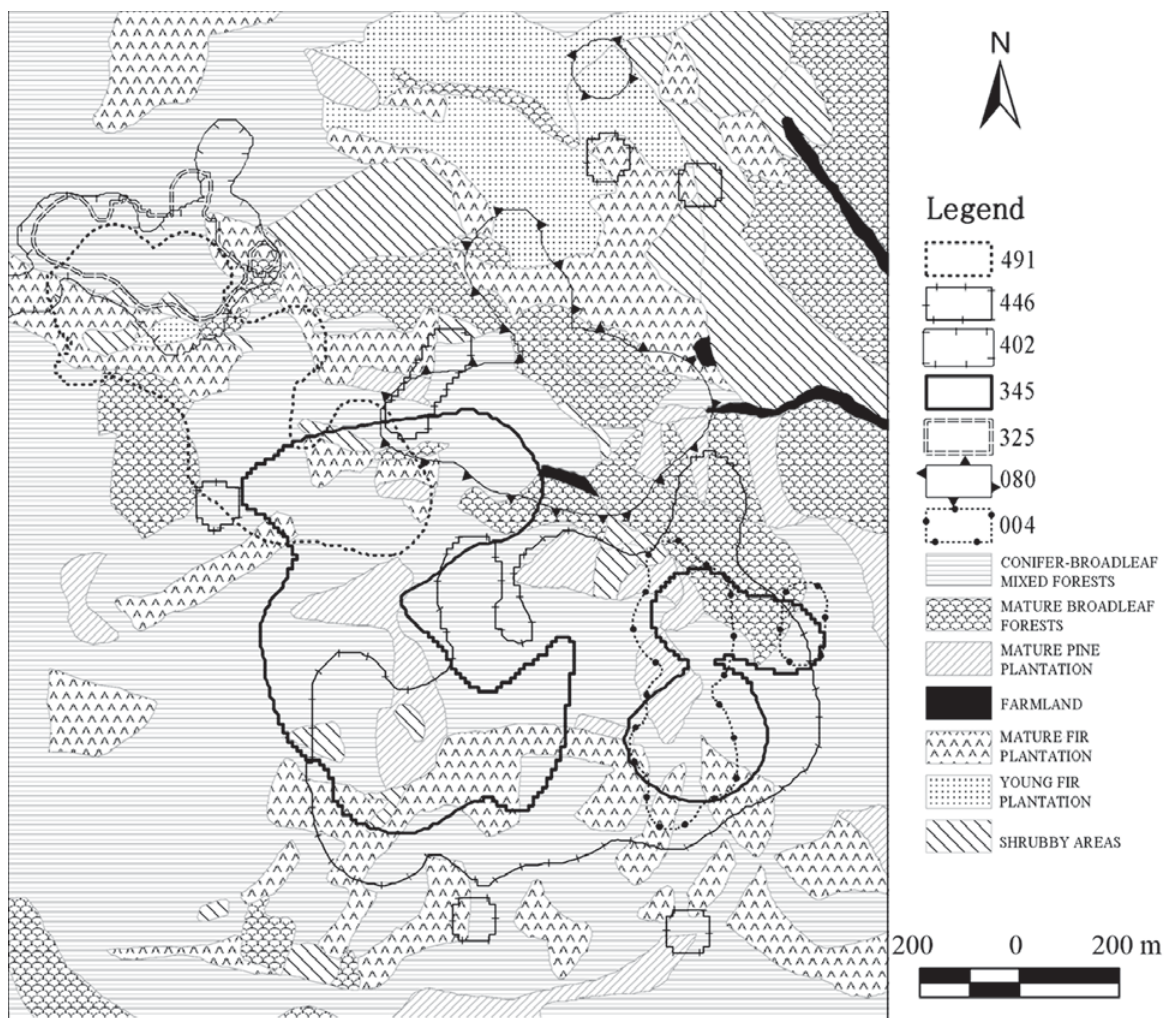
Figure 1. Habitat types and home range contours of the tracked male Reeves's pheasants in 2000 in the study site in Dongzhai National Nature Reserve, Henan Province, China. The numbers in the legend represent individual males.

compared the size of $CEP_{0.50}$, i.e. the median Circular Error Probable (Moen et al. 1997), to the home range area, to assure that telemetry errors were acceptable for home range analysis (Moser & Garton 2007). Bird locations were divided into four seasons: spring (March-May), which encompassed most mating activity; summer (June-August), when most females were rearing broods; autumn (September-November), when young were still associated with their female parent; and winter (December-February), when birds gathered into flocks.

Data analyses

Home range was estimated based on 100% minimum convex polygon (MCP) and 95% fixed kernel estimation using Animal Movement software, an extension to ArcView 3.2, based on detected locations (Hooge & Eichenlaub 1997). We defined 60% fixed kernel as the core area. All fixed kernel estimations were based on least squares cross validation for deriving smoothing factor (Hooge & Eichenlaub 1997). MCP has commonly been used to estimate home range but is sensitive to sample size, and we reported MCP estimates on annual home range only to draw comparisons between our findings and those of previous studies. The fixed kernel estimator is preferred because it is based on nonparametric assumptions and more accurate relative to other home range estimators (Seaman & Powell 1996). Therefore, we used the home range size obtained by 95% fixed kernel contours for additional analyses. Seasonal home ranges and core areas were

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estimated for individuals with ≥30 locations in a season, while the annual home ranges and core areas were estimated for individuals with ≥30 or more locations in a year. Average distance between consecutive locations (every 12 hours) was calculated and used as an index of daily mobility for each individual (hereafter; daily movement) (Vega Rivera et al. 2003, Cardinal & Paxton 2005).

Home range composition was estimated based on the land cover map (Xu et al. 2007) in Arcview 3.2. We used two measurements to quantify site fidelity: FIDELH is the percentage of an individual's home range within the home range of the previous season or year (Phillips et al. 1998, Perelberg et al. 2003); and FIEDLL is the percentage of an individual's locations within the home range of the previous season or year (Phillips et al. 1998).

We were not able to test for year effects because of small sample size in each year, and pooled radio locations from 2000 to 2003 to ensure adequate sample size for seasonal analysis. We assumed the yearly effect was small because habitat remained relatively unchanged (J-L. Xu, unpubl. data) and human disturbances were relatively constant, because our study site is a protected nature reserve. We used only one year of data for birds tracked more than one year when we estimated seasonal variations of home range, core area and movement. Values of home ranges and core areas were natural log-transformed to meet assumptions of normality. One-way ANOVA was used to test whether the home range areas, core areas and daily movements differed among seasons. Tukey *post hoc* tests were used for pair-wise comparisons. Seasonal changes in home range size were also assessed with linear and quadratic trends. Pearson correlation was used to test the relationship between the home range and core area among seasons and years.

We used an α level of $P \leq 0.05$ for all statistical tests. Unless otherwise mentioned, means are provided with ±1 standard deviation (SD). Statistical analyses were performed using SPSS 10.0.1 for Windows (SPSS Inc. 1999).

Results

Home range and core area
Seventeen male Reeves's pheasants were captured (nine, five, and three individuals in April 2000, 2001 and 2002, respectively), which represented about 15% of the male population at the study site (Zhang

2002). The average tracking duration of each bird was 174.0 ± 150.2 days (range: 2-536 days). We assessed accuracy of telemetry by comparing coordinates of 72 known points with those estimated using telemetry. The average telemetry location error was 10.30 ± 5.28 m (mean ± 1 SD), and the size of $CEP_{0.50}$ was 0.03 ha, which was small compared to the home range. Therefore, our telemetry locations were reliable for estimating home range (Moser & Garton 2007). Annual average home range size was 44.9 ± 24.6 ha based on minimum convex polygons, and 23.8 ± 13.7 ha based on 95% fixed kernel estimator (N=15). Home range overlaps were common (see Fig. 1). Core area was 4.2 ± 3.5 ha (N=15), accounting for $17.1 \pm 6.1\%$ of the corresponding home range. Core area size was positively related to home range size (r=0.87, P=0.001). Home range size varied among seasons ($F_{3,29}$ = 2.22, P=0.05, Table 1) and declined linearly from spring to winter (P=0.02). Home range size differed significantly (Tukey HSD: P=0.03) between spring and winter, but did not differ among winter, summer and autumn (Tukey HSD: winter vs summer, P= 0.180, winter vs autumn, P=0.39). The core area (see Table 1) tended to increase from spring to summer and decreased in autumn and winter (F=1.99, P=0.14). There was a linear trend from spring to winter (P=0.04).

Conifer-broadleaf mixed forests occupied the largest part of both the home range and core area of male Reeve's pheasants, followed by Chinese fir forests, broadleaf forests, masson pine plantations, shrubs and young replanted plantations (Table 2).

Movements and fidelity
Daily movements (see Table 1), measured as the distance between two consecutive locations detected in approximately 12 hour intervals, differed between seasons ($F_{3,29}$ = 4.90, P=0.01). Daily movements showed a decreasing trend from spring to winter (P=0.01). Daily movements in spring were

Table 1. Seasonal home range, core area and daily mobility (mean ± 1 standard deviation) of male Reeves's pheasant in central China.

Season	Individuals	Home range (ha) (95% fixed kernel)	Core area (ha) (60% fixed kernel)	Daily mobility (m)
Spring	12	23.9 ± 13.7	4.5 ± 3.2	233.6 ± 80.9
Summer	9	21.8 ± 13.4	5.3 ± 3.6	191.2 ± 50.2
Autumn	6	16.9 ± 7.7	3.0 ± 1.2	179.3 ± 41.9
Winter	5	9.5 ± 4.3	1.9 ± 0.8	132.3 ± 18.8

Table 2. Home range and core area composition (%, mean ± 1 standard deviation) of male Reeves's pheasant in central China. Mixed = conifer-broadleaf forests. Pine = masson pine forests. Fir = Chinese fir forests. Replanted = young Chinese fir forests.

Code	Season	Mixed	Broadleaf	Pine	Fir	Shrub	Replanted	Farmland
Home range	Spring	59.39 + 7.74	6.78 + 4.74	4.90 + 6.64	21.36 + 7.92	6.46 + 2.96	1.11 + 1.21	0.01
	Summer	59.75 + 18.82	7.36 + 5.94	4.84 + 7.94	19.89 + 8.25	5.31 + 5.07	2.86 + 6.28	0.01
	Autumn	56.13 + 21.31	7.16 + 5.65	4.75 + 6.88	20.40 + 7.23	8.19 + 6.35	3.38 + 6.69	-
	Winter	55.73 + 25.78	5.45 + 3.65	8.99 + 13.65	11.86 + 5.36	15.90 + 20.02	2.07 + 4.30	-
Core area	Spring	64.34 + 22.12	5.41 + 10.67	7.46 + 9.56	17.62 + 18.40	3.83 + 4.85	1.34 + 3.49	-
	Summer	64.24 + 28.08	1.40 + 2.77	6.65 + 9.84	19.92 + 19.32	4.57 + 7.56	3.22 + 9.14	-
	Autumn	64.11 + 30.69	5.12 + 7.13	6.02 + 9.77	11.66 + 8.50	11.36 + 20.23	1.74 + 4.25	-
	Winter	63.85 + 34.54	0.15 + 0.34	12.52 + 17.97	12.12 + 16.61	10.25 + 15.85	1.12 + 2.50	-

almost twice (Turkey HSD: P = 0.004) that of winter, but there were no differences among winter, summer and autumn distances (Tukey HSD: winter vs summer, P = 0.105, winter vs autumn, P = 0.29).

For five males that were radio-tracked in consecutive years, we found that on average, $61.0 \pm 17.7\%$ of their home range and $86.2 \pm 16.7\%$ of their detections in a given year were within the home range of previous year. Home range overlap among seasons of each individual tended to increase from spring to winter (Table 3): $65.9 \pm 15.8\%$ between spring and summer and $74.0 \pm 18.8\%$ between fall and winter.

Discussion

Although some information is available on home ranges of Reeves's pheasant (Sun et al. 2003, Xu et al. 2005), and seasonal habitat use based on compositional analysis (Xu et al. 2007), little has been published on home range attributes, including home range composition, daily movements and site fidelity. This information is important for successful conservation of Reeves's pheasant (Phillips et al. 1998, Perelberg et al. 2003, Mori 2005).

Table 3. Seasonal site fidelity (mean ± 1 standard deviation) of male Reeves's pheasants in Dongzhai National Nature Reserve. FIDELH = the percentage of an individual's home range within the home range of the previous season. FIDELL = the percentage of an individual's detected locations within the home range of the previous season. N = the sample size of each season pairs.

Measures of site fidelity	Summer vs spring	Autumn vs summer	Winter vs autumn
FIDELH (%)	65.92 + 15.76 (N = 8)	66.20 + 13.59 (N = 6)	74.02 + 18.84 (N = 5)
FIDELL (%)	73.50 + 19.23 (N = 8)	63.79 + 17.58 (N = 6)	75.49 + 7.55 (N = 5)

Estimating home range can provide vital insight into important ecological processes (Horne & Garton 2006). Studies on Cabot's tragopan *Tragopan caboti* (Young et al. 1991) and Ring-necked pheasants *Phasianus colchicus* (Smith et al. 1999) have shown that home range size varied seasonally and was larger in spring compared to other seasons, particularly winter. Our results indicated a similar pattern for male Reeves's pheasants. The larger spring home range of male Reeves's pheasants could be related to several factors including: 1) mate-searching, 2) defense of territories, and 3) securing food resources for increased energetic demands associated with the breeding season. Smaller winter home ranges may result from a trade-off between food requirements and cover needed to protect against increased predation. During winter, male Reeves's pheasants decrease activity, concentrating within optimal habitats, e.g. shrubs and mixed forests (Xu et al. 2007), likely resulting in smaller home ranges.

Core areas are areas of concentrated use (Somers & Nel 2004), often with the most dependable resources (Leuthold 1977), and of great importance to individuals regardless of the season. Core areas of Reeves's pheasants in our study were often composed of conifer-broadleaf mixed forest. This type of forest provides stable food resources for Reeves's pheasants including buds in spring and acorns in autumn and winter (Xu et al. 2007). This may explain the relative stability of core areas across seasons.

We observed high overlap in a given pheasant's home range among years and seasons. This pattern is inconsistent with results published by Fang & Ding (1997), who reported that Reeves's pheasants showed altitudinal movements across seasons, but agree with studies by Wu (1979) and Hu & Wang (1981), who reported that Reeves's pheasants did

not shift their home range across seasons. It may imply that resources at our study site were relatively stable across years and seasons, and met the needs of Reeves's pheasant. Habitat use by Reeves's pheasant in our study was relatively similar across seasons, and birds concentrated their activities mainly in conifer-broadleaf mixed forests (Xu et al. 2007), suggesting that habitats within core areas were sufficient to support birds' year-round activities.

Conclusions

Currently, there is a scarcity of knowledge about home range composition, daily movement and site fidelity of the Reeves's pheasant, limiting the establishment of effective conservation strategies. Our results provide baseline data regarding the spatial ecology of this endangered species. Conservation management of the Reeves's pheasant often involves establishing protected areas and restoring existing habitat (Madge & McGowan 2002, Zhang et al. 2003). Our results showed that the home range size of Reeves's pheasant became smaller from spring to winter, and that Reeves's pheasants were most active in spring, suggesting that major habitat management activities should avoid the most active period, i.e. spring. Because pheasant core areas remained stable across seasons, resource managers should strive to maintain the spatial continuity of habitat composition in core areas. Moreover, the strong site fidelity of male Reeves's pheasants may make them particularly susceptible to habitat change or loss, and creating additional habitat may be insufficient without translocation since they are unlikely to colonise new areas.

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