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Source: The Wilson Journal of Ornithology, 125(3):491-501. 2013.
Published By: The Wilson Ornithological Society
DOI: http://dx.doi.org/10.1676/12-151.1
URL: http://www.bioone.org/doi/full/10.1676/12-151.1

The Wilson Journal of Ornithology 125(3):491–501, 2013

HOME RANGE EXTENSION AND OVERLAP OF THE ORNATE TINAMOU (*NOTHOPROCTA ORNATA*) IN AN ANDEAN AGRO-ECOSYSTEM

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ABSTRACT.—Very little is known about the home range and movement patterns of tinamous. The Ornate Tinamou (*Nothoprocta ornata*), a species of the central Andes that is important for cynegetic and biomonitoring purposes, was previously reported to have a very small territory (2.43 ha). This was based solely on field observations. In order to gain a better understanding of the movement patterns, home range size, and home range overlap of this species, we radio tracked 12 adult individuals in an Andean agro-ecosystem for a full year. The birds remained within their home ranges all year; 100% MCP (minimum convex polygon) home ranges were 43.8 ± 21.6 ha (22–85 ha), 95% kernel home ranges were 58.8 ± 31.9 ha (25–118 ha) and 50% kernel core areas were 15.3 ± 8.9 ha (6–33 ha). Only two birds, probably sub-adults, showed extensive movement patterns before their death. Individuals overlapped their home ranges extensively (from 30–98% with 2–3 tagged individuals), but these values were probably higher because a small proportion of the population was tagged. No sexual differences were detected in home range size or overlap. Our results support the usefulness of Ornate Tinamou as a sentinel species in biomonitoring studies and highlight the need for further research into the philopatric and dispersion behavior of juveniles before planning cynegetic strategies. *Received 21 September 2012. Accepted 20 March 2013.*

Key words: cynegetic use, Neotropical region, radio tracking, sentinel species, Tinamidae, triangulation.

Tinamous are among the least studied bird species, despite their evolutionary, ecological, and cynegetic importance in Latin American countries. Basic ecological knowledge about their population density, abundance, home range size, movements, and dispersion patterns are important in order to develop management strategies.

Early studies on tinamous that focused on their movements, home range sizes, and home range overlap were based on field observations of few individuals (Schäfer 1954; Pearson and Pearson 1955; Lancaster 1964a, b). The home ranges reported varied from 0.1 ha in the Highland Tinamou (*Nothocercus bonapartei*) (Schäfer 1954) to 24 ha in the Brushland Tinamou (*Nothoprocta cinerascens*; Lancaster 1964a). To date, only one study on home range has used the radio-tracking technique and reported mean home range sizes of 16 and 19 ha for the Spotted Nothura (*Nothura maculosa*; Thompson and Carroll 2009). In general, tinamous are considered resident, non-migratory species, with the probable exception of the genus *Tinamotis* (Cabot 1992, Davies 2002).

Using existing knowledge about the general residence parameters and the relatively small home range sizes of tinamous as a starting point, Garitano-Zavala et al. (2010) proposed two tinamou species as potential sentinel species of chemical hazards produced by mining activities in the Andean region. The tissue concentrations of trace metals in the birds captured in polluted mining areas were significantly higher than those captured in control areas (Garitano-Zavala et al. 2010). In order to gain a better understanding of the relationship between the trace metal tissue concentrations and the pollutant dynamics in the environment in which they live, it is essential to find out about the movements, home range sizes, and home range overlap of these tinamou species. If several individuals are resident in relatively small and overlapping home ranges, the trace metal concentrations in the tissues of the birds will reflect exposure to soil, water, or food pollution on a local level.

One of these two species is the Ornate Tinamou (*Nothoprocta ornata*), which inhabits the South American Andes from southern Peru to northern Chile and Argentina at altitudes that range from 2,500–4,800 m (Cabot 1992, Davies 2002). The only previous studies on home range size and movements for this species were based on field

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observations by Pearson and Pearson (1955), who reported a nesting and feeding territory of 2.43 ha (6 acres) for a nesting pair, which would also suggest that this species is territorial and resident.

The highly variable reports concerning the home ranges of tinamou species, especially the small area previously reported for the Ornate Tinamou, require new studies in order to obtain more reliable measurements of home range and residence parameters.

Although it has been postulated that radio transmitters could negatively affect birds and may result in biased data (Barron et al. 2010), studies with ecologically similar bird species have demonstrated no negative effects (Hernández et al. 2004, Palmer and Wellendorf 2007, Terhune et al. 2007). We consider that radio tracking is not only adequate, but may be the only way to study tinamous in the field, given their reserved behavior (Cabot 1992, Davies 2002, Brennan 2004). The aim of the present study was to gain an insight into the movements, home range size, and home range overlap of the Ornate Tinamou by means of year-round monitoring of several radio-tagged sympatric males and females in a typical Andean agro-ecosystem on the Bolivian high plateau.

METHODS

Study Area.—We captured and studied wild Ornate Tinamou individuals in Qurpa (16° 40′ S, 68° 51′ W; 3,850 to 4,100 m asl), a rural locality on the Bolivian high plateau east of the Desaguadero River and south of Lake Titicaca. The total surface area used for radio tracking was approximately 820 ha. The climate is cold all year round, with greater daily than seasonal temperature fluctuations (minimum average monthly temperature 5.7 °C; maximum average monthly temperature 9.9 °C), dry in winter (minimum average monthly precipitation 5.1 mm) and rainy in summer (maximum average monthly precipitation 133.7 mm; SENAMHI 2012).

The mountainous landscape is a heterogeneous mixture of Andean crops (barley, bean, alfalfa, potatoes, oca, onion and quinoa, with no fields larger than a quarter of a hectare), interspersed with recently harvested and fallow fields and non-agricultural lands. The non-agricultural areas have bunch grasses, including *Stipa ichu* and *Festuca* spp., with a mixture of spiny and resinous shrub vegetation (e.g., *Baccharis incarum*, *Adesmia miraflorensis*, *Tetraglochin cristatum* and *Satureja boliviana*) and scattered rocky patches. These non-agricultural areas are used for grazing sheep, llamas and cattle. Several weed species grow in both the active and inactive agricultural areas. Crops are grown on an annual basis: sowing takes place between September and January, followed by the crop harvest between May and July, and the fields are then left ploughed for the next sowing season.

Evaluation of Effects of Radio Tagging.—We selected 12 g necklace tags (R1–2D model, Holohil System, Carp, Ontario, Canada) with a 24-month lifespan that represent 2.7% of the minimum adult body weight reported for this species (Davies 2002). Necklaces are the most common tagging system used for game birds (e.g., Novoa et al. 2002, Oakley et al. 2002, Pérez et al. 2004, Watson et al. 2007) that have the same size and ground-dwelling habits as the Ornate Tinamou, and were used successfully with the Spotted Nothura in a study by Thompson and Carroll (2009). Necklaces are recommended for bird species that do not fly frequently (Marcström et al. 1989, Kenward 2001). Studies on the ecologically similar but smaller Northern Bobwhite (*Colinus virginianus*) demonstrated that these radio transmitters had no negative effects on energy level (Hernández et al. 2004) or survival (Palmer and Wellendorf 2007, Terhune et al. 2007).

To evaluate the effects of tagging on the Ornate Tinamou (Murray and Fuller 2000), we attached necklace tags to three adult individuals (two females and one male) that were born and bred in captivity in the city of La Paz (3,450 m asl). These birds were held with seven other individuals in an enclosure measuring 8 × 5 m. To imitate the natural conditions in the wild, the enclosure had resinous shrub and bunch grasses, and the birds were exposed to natural weather conditions and fed mainly barley grains and alfalfa leaves, the largest and most frequently consumed items among wild individuals (Garitano-Zavala et al. 2003).

The necklaces were firmly attached to prevent tag loss over the head, and a gap of 7 mm was left between the elastic lace and the neck to avoid blocking the esophagus. For 6 months we observed the birds' behavior. We looked for abnormal movements, food plugged in the esophagus, bills lodged in the lace (Sorenson 1989), antennae or tags becoming tangled in vegetation (Brennan 2004), and premature tag

TABLE 1. Individual code assigned to each radio-tagged Ornate Tinamou (a combination of the channel number and the sex, F: female or M: male), body mass, days tagged (days from the tag attachment until the end of the study, death, or signal loss), causes of individual signal loss (a: tag was found with signs of predation on the bird; b: tag was found with no signs of predation on the bird; c: tag was not found; NL: the tag was not lost until the end of the study), total days of radio tracking by triangulation (DRT-T) and total months of radio tracking by homing (MRT-H) and triangulation (MRT-T) are shown.

Individual code	Body mass	Days tagged	Causes of signal loss	DRT-T	MRT-H / MRT-T
05M	420	310	a	32	3 / 8
10M	510	308	NL	44	11 / 11
15M	505	32	a	4	0 / 1
20F	340	128	a	16	3 / 4
40F	530	374	NL	44	10 / 11
55F	650	270	b	36	8 / 8
60F	(*)	251	c	20	6 / 5
65F	740	308	NL	44	11 / 11
70F	595	309	NL	44	11 / 11
75M	330	23	a	8	1 / 1
90M	490	261	a	28	3 / 7
99M	570	309	NL	44	11 / 11

(*) Because of the stress suffered during capture, individual was released without being weighed.

loss. When we removed the tags, we examined the skin for wounds and lacerations. We weighed the three birds and three other untagged adult individuals (two females and one male) before and after the 6 experimental months to evaluate the tagging effect with repeated ANOVA measurements (Zar 2010). We did not consider sex, because the sample was small and little effect has generally been reported (Barron et al. 2010).

Radio Tracking.—We trapped 12 Ornate Tinamou individuals (six males and six females) between September 2006–March 2007 with a mobile trap technique that is used by local hunters in Qurpa. The technique involves two teams of three people; each team walks slowly and quietly through the hills, searching from high natural observatories for any movement that may reveal Ornate Tinamou individuals in the crops, bunch grasses, or shrubs. Once a bird is sighted, a member of the team runs close to the bird, causing it to hide and squat under grass or shrubs, but not to flush. Two other team members who know the exact position of the bird slowly walk up to it and gently place a cotton net attached to two 3-m poles over the vegetation under which the bird is hiding. Finally, the bird is incited to flush and becomes tangled in the net.

The equipment used for radio tracking comprised two sets of Telonics TR-4, Telonics ''H'' Adcock RA-2A antennae (Telonics Inc., Mesa, Arizona, USA), hand-held GPS units (Garmin eTrexVista, Garmin International Inc., Olathe, Kansas, USA) and compasses. For each trapped bird, we recorded the GPS position, date, time, body mass and sex (by cloacal examination). There is no reliable field method for accurately determining the bird's age. We attached necklace tags as we had for the captive birds and fitted a numbered metal ring on the left leg before releasing it at the same capture location. Handling took no longer than 10 mins. Tag VHF signals were within the range of 150–154 MHz. The code for each individual was the receiver's channel number plus sex (Table 1). Tag weight percentages ranged from 1.6–3.6%.

We radio tracked each bird using triangulation and homing. With three birds tagged between September and November 2006, we defined fixed triangulation points, taking into account accessibility and signal detection quality on two parallel routes. The first route (5.16 km) was at the road across the plain (approximately 3,860 m asl); the second route (4.02 km) was 2 km away on the mountain summits (between 4,070–4,270 m asl). On each route, we established seven fixed points. In order to obtain four consecutive bearings at each location as quickly as possible (Kenward 2001), we matched to each fixed point a neighboring point 50 m away, assuming that the movement of any bird in the time taken for the observer to move that distance was negligible.

The precision and accuracy of the telemetry system for triangulation were tested following the methods suggested by White and Garrot (1990) and Withey et al. (2001). We attached three test transmitters to wooden posts at a height of 30 cm in the areas where Ornate Tinamou individuals were observed and/or captured. The mean distance between the test transmitters and fixed points was 1.69 ± 0.60 km. An observer who did not know the locations of the test transmitters obtained the bearings from all fixed points. We estimated the test transmitter positions using Location of a Signal Software 4.0 (LOAS 2009). To minimize the error of intersection of the triangulated bearing, we used only triangulations that showed an angle between the bird and the fixed points of between 60° and 120°.

The mean distance between the estimated locations and known test transmitter positions was 193.67 m (SD = 75.31), and the mean and standard deviation of bearing errors was −0.016° ± 12.21. Based on these results, we concluded that our triangulation system was not biased and was accurate enough to estimate home ranges and overlap, but not habitat or resource use, given the birds' highly heterogeneous mixture of small-surface habitats (Montgomery et al. 2011).

Twice a month, between December 2006 and October 2007, two observers (one per route) walked early in the morning in the same direction along the routes (NW to SE or SE to NW) and returned in the opposite direction in the afternoon. At each pair of opposite fixed points, the observers recorded bearings for each tagged bird. Bearings were taken simultaneously for each bird by means of walkie-talkies. The time taken to travel between each telemetry location was at least 20 mins, which was chosen to minimize dependency and to obtain an adequate sample size (White and Garrot 1990, Powell 2000). As fixed points were visited twice a day, it was possible to locate each bird 14 times per day and 28 times per month, but because of topography interference this maximum was reduced.

The homing technique (White and Garrot 1990) was carried out by one observer for a period of 14 months (Jan 2007 to Feb 2008), six times per month, each time for a different, randomly selected individual. Because of adverse weather conditions, fewer than six individuals were radio tracked during some months. Each individual was radio tracked every 2-3 months at the beginning of the study, but as the number of birds decreased because of predation or signal loss, this rate increased to almost one register per month for each individual. Table 1 shows the total number of homing months per bird. From sunrise to sunset, the selected bird was followed on foot by means of radio contact until visual contact using 10 × 25 binoculars was achieved. Every 10 mins, the observer obtained the GPS position, the bearing, and the exact distance (m) to the bird by using a Laser Rangefinder Bushnell Yardage Pro (Bushnell Performance Optics, Overland Park, Kansas, USA). The bird's position at each visual contact was determined with Location of a Signal Software 4.0 (LOAS 2009). As these sequential locations were not independent, we did not use them for home range estimation. We used the data to: 1) resight birds and evaluate the accuracy of the positions calculated using the triangulation method and construct a 100% MCP (Mohr 1947) with all homing locations using RANGES VII software (South et al. 2005); and 2) evaluate the eventual effect of time and season on the spatial distribution of the birds and graphically differentiate homing locations by month and time of day (morning was classed as 0700–1030, noon as 1130–1430 and afternoon as 1530–1830). Using this information, we defined the method of working with triangulation data for home range estimation.

Home Range Estimation.—We entered all bearings obtained for each bird by triangulation into the Location of a Signal Software 4.0 (LOAS 2009) to calculate the birds' locations. We excluded unacceptable locations and only accepted those that showed an angle between the bird and the fixed points from 60° to 120° and error ellipses ≤2 ha (although 80% of accepted locations had ≤1 ha error ellipses). To test the degree of spatiotemporal relatedness of the locations, we determined autocorrelation using Schoener's ratio t^2/r^2 (Schoener 1981), where t^2 is the mean squared distance between consecutive locations and r^2 is the mean squared distance from each location to the arithmetic mean coordinates of all locations, using RANGES VII software (South et al. 2005).

We calculated the home ranges with 100% MCP (Mohr 1947) and density contours of 95% using fixed-kernel estimator with *ad hoc* choice of *h* (Worton 1989), because both permit direct comparisons with other studies. We also estimated 50% kernel contours as core areas. Kernel estimators are sensitive to sample size, so we only calculated home ranges and core areas for birds with 40 or more locations, as recommended by Seaman et al. (1999). We obtained all home range calculations using RANGES VII software (South et al. 2005) and assessed sex differences using the non-parametric Mann-Whitney U-test, considering differences significant when $P < 0.05$ (Zar 2010).

We evaluated the total overlapping areas of individual home ranges (100% MCP) and core areas (50% kernel) using a Geographical Information System, ARCVIEW 3.2a (ESRI 1999), with which we obtained both the total overlapped surface area with certain individuals and the total overlapped area with all individuals versus the total free area. We performed sex comparisons using the Mann-Whitney U-test, considering differences significant when $P < 0.05$ (Zar 2010). For all statistical tests, we used PASW Statistics 18 (PASW 2009).

RESULTS

Effect of Radio Tags on Captive Individuals.—We did not detect any major effects of the tags on the three captive birds. No tags or antennae became tangled in the vegetation, nor were they lost prematurely. However, we did notice that the necklaces deteriorated, so they may have broken and gone missing if they had been used for a longer period of time. After we removed the tags, no bruises or lacerations were found on the skin that had been in contact with the radio tag. No individual's weight was significantly different after the 6 experimental months, for tagged or untagged individuals (factor before and after tagging: $F_{1,4} = 1.46$; $P = 0.29$; factor tagged and untagged birds: $F_{1,4} = 3.97$; $P = 0.12$).

Wild Radio-Tagged Birds Lost During the Study.—Only five of the 12 tagged birds kept the radio tag until the end of the study. The tags of the other seven birds were found in the field or the signal was lost, which occurred between 23 days and 10 months (Table 1). Five of these seven birds were probably depredated (representing 42% of the total tagged birds), because the transmitter was still emitting when found and feathers were scattered nearby. In addition, tooth marks were found on several transmitters, which led us to believe that the Andean fox (*Pseudalopex culpaeus*) killed these birds, although other predators such as the Colocolo cat (*Leopardus colocolo*), or even raptors such as the Black-chested Buzzard-Eagle (*Geranoaetus melanoleucus*) or the Variable Hawk (*Geranoaetus polyosoma*) may have been responsible. Of the other two tags, one was found in the field with no predation signs and the signal of the other was lost and the tag never found (Table 1).

TABLE 2. Total valid locations obtained by homing radio tracking for each Ornate Tinamou (F: female or M: male), area size, and total linear distance between capture site (C) and site of tag loss (L). NC = Data not calculated.

Individual	Locations	MCP 100% (ha)	Distance C-L (m)
05M	208	3	317
10M	935	11	
15M	0	NC	384
20F	212	34	1,522
40F	836	8	
55F	775	12	205
60F	370	111	1,184
65F	1,053	13	
70F	776	9	
75M	62	0.08	133
90M	197	6	121
99M	886	13	

Bird Movements.—Two birds (15M and 75M) died before we could obtain more than one month of homing and/or triangulation data (Table 1), and therefore it was not possible to identify their movement patterns. For eight of the other 10 birds, we did not observe any significant movements and therefore concluded that they were residents of a particular area. Homing data showed that the monthly and daily positions were equally distributed within the polygon area without any pattern, which would indicate the absence of any monthly or daily effects on bird location, and for the birds whose signal was eventually lost, the linear distances between capture and signal loss sites were less than 500 m (Table 2).

Only two birds showed a non-resident pattern and showed the maximum distances between the capture site and the site of tag loss (Table 2). Bird 20F (whose body weight suggested it was probably a sub-adult) moved 1,522 m northwest from the capture point in March 2007 to the point of tag recovery in July 2007. The homing 100% MCP was expressed in two polygons and triangulation locations were between the points of capture and death, which would suggest gradual movement. Bird 60F showed a large MCP area and a long distance between capture and last signal reception (Table 2). Locations revealed a monthly pattern, suggesting that this was a non-resident bird moving across a wide area before the signal was finally lost.

TABLE 3. Total radio tracked days, valid locations, home range (100% MCP and 95% kernel) and core area (50% kernel) size for each Ornate Tinamou (F: female or M: male) obtained using the triangulation method. t^2/r^2 is Schoener's ratio. NC = Data not calculated.

Individual	Valid locs.	100% MCP (ha)	95% kernel (ha)	50% kernel (ha)	t^2/r^2
05M	178	30	37	10	1.81
10M	113	85	118	33	1.50
15M	31	NC			
20F	55	NC			
40F	192	37	45	11	1.64
55F	100	26	34	8	1.72
60F	33	NC			
65F	86	63	91	22	1.63
70F	124	53	69	18	1.69
75M	21	NC			
90M	163	22	25	6	1.76
99M	71	34	51	14	2.07
Mean ± SD		43.8 ± 21.6	58.8 ± 31.9	15.3 ± 8.9	

Home Range Size and Core Areas.—We recorded locations for homing and their 100% MCP areas (Table 2). We calculated the home range and core area from year-round triangulation locations only for the eight birds that were resident and had more than 40 valid locations (Table 3). The locations of five of the eight birds were observed over a period of 11 months, and the total number of radio-tracking days was 44 (Table 1). Homing 100% MCP polygons were fully or mostly included in the triangulation polygons of 100% MCP and 95% kernel, which confirm that the accuracy of the positions calculated by triangulation was sufficient (Fig. 1). In addition, the calculated areas included the capture-release and tag-recovery points, or at least the points nearest to those areas (Fig. 1). Since Schoener's radius values for seven birds were between one and two, and for one bird, the value was just over two (Table 3), we considered the home range and core area calculations to be reliable.

We calculated individual and mean home ranges by 100% MCP and 95% kernel together with the 50% kernel core area (Table 3). We recorded sex-differentiated means (Table 4). In all cases, home range areas were bigger when calculated using the kernel method. Home ranges calculated by 100% MCP never exceeded 1 km^2 and ranged from 22–85 ha. Core areas ranged from 6–33 ha. No significant sex differences were found in 100% MCP ($z = -0.58$; $P = 0.56$), 95% kernel ($z = -0.29$; $P = 0.77$) or core areas ($z = -0.29$; $P = 0.77$).

No positive correlation was found between the total number of locations and the home range size (100% MCP: $r_s = -0.21$; $P = 0.61$; 95% kernel: $r_s = -0.38$; $P = 0.35$) or core area ($r_s = -0.38$; $P = 0.35$). Therefore, we believe that the number of locations was sufficient to carry out the calculations.

The eight tagged birds formed two clusters in the study area, both consisting of four birds (two males and two females) separated in two parallel valleys (Fig. 2). The presence of the birds in these clusters does not necessarily mean that they were paired.

Home Range Overlap.—All the individuals, regardless of sex, overlapped their home range with two or three other tagged males or females (Table 5, Fig. 2). The mean proportion of the total area of home range overlap was greater than 50% (Table 5); most individuals overlapped their core area with the same individuals that overlapped their home ranges, but to a lesser degree. During the homing, we observed untagged birds feeding, walking, or flushing in the home ranges of tagged birds (up to nine individuals feeding together in the non-reproductive season), so the proportion of overlap was actually greater.

The maximum overlap values detected were between male 10 and female 70 (Table 5, Fig. 2), which were a pair, according to homing observations. No other pairs of radio-tagged males and females were observed.

There was a wide variation in the occurrence and proportion of the home range and core area overlap between birds, but the patterns were not determined by sex. There was no difference between the proportion in which the total

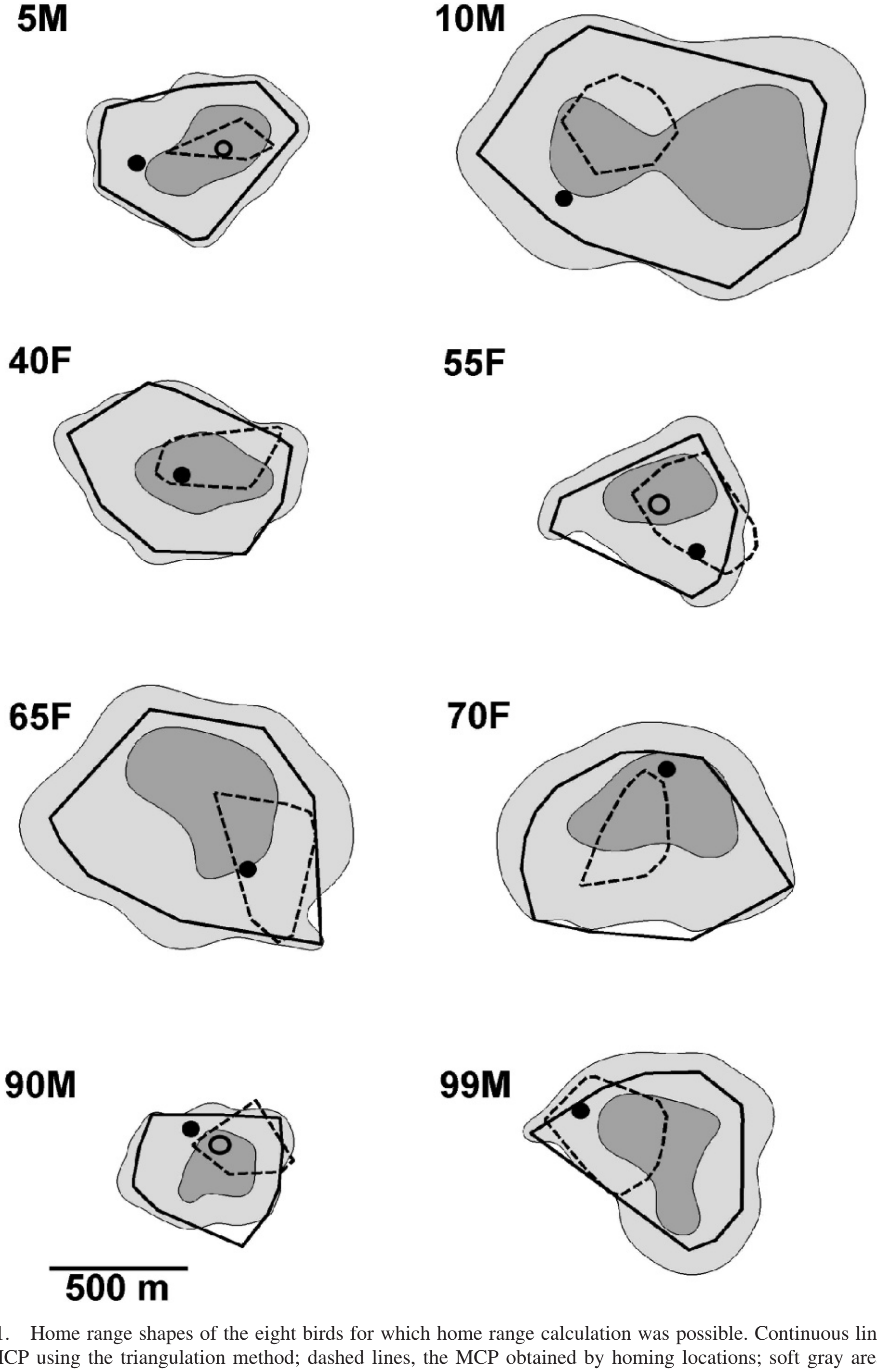

FIG. 1. Home range shapes of the eight birds for which home range calculation was possible. Continuous lines show 100% MCP using the triangulation method; dashed lines, the MCP obtained by homing locations; soft gray areas show kernel 95% home range; and dark gray areas, 50% kernel core areas. The closed circle shows capture point and the open circle shows tag recovery location.

TABLE 4. Year-round home range (100% MCP and 95% kernel) and core area (50% kernel) mean ± standard deviation for Ornate Tinamou males and females in the Bolivian Andes.

Group	100% MCP (ha)		95% kernel (ha)		50% kernel (ha)	
	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range
Male (n = 4)	43 ± 29	22–85	58 ± 42	25–118	16 ± 12	6–33
Female (n = 4)	45 ± 16	26–63	60 ± 25	34–91	15 ± 6	8–22

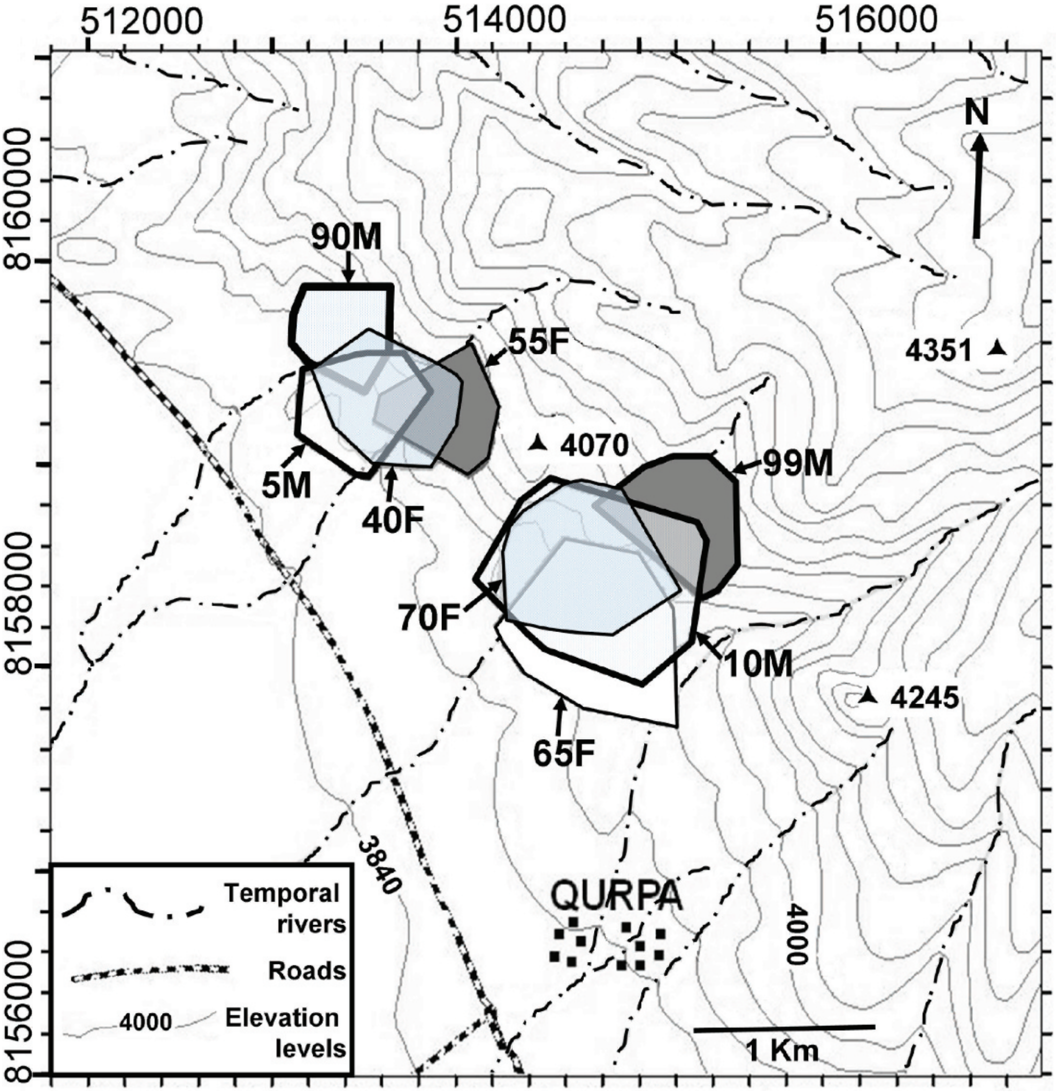

FIG. 2. Position in the study area and home range overlap (MCP 100%) of the eight birds for which home range calculation was possible (each polygon identified with the individual code). Bold-lined polygons are males; light-lined polygons are females.

TABLE 5. Total size, percentage of home range, and the number of other tagged individuals that overlap on the home range (100% MCP) and core area (50% kernel) of each individual Ornate Tinamou.

	Total home range overlap 100% MCP			Total core area overlap 50% kernel		
Individual	ha	%	Number of individuals	ha	%	Number of individuals
05M	21	71	3	6	57	2
10M	77	90	3	19	56	3
40F	33	88	3	8	77	2
55F	14	53	2	3	34	2
65F	43	69	2	13	59	2
70F	52	98	3	5	28	2
90M	6	30	2	0	0	0
99M	13	38	2	2	17	1
Mean ± SD	32 ± 24	67.1 ± 24.9		8 ± 6	41.0 ± 25.6	

individual home range size of males and females overlapped ($z = -0.87$; $P = 0.39$, for area and percentage) or that in which their core area overlapped ($z = -0.58$, $P = 0.56$ for area; $z = -1.16$, $P = 0.25$ for percentage). Moreover, males do not overlap differently with males or females ($z = -1.08$, $P = 0.28$ for home range area; $z = -1.07$, $P = 0.29$ for home range percentage, $z = -0.88$, $P = 0.38$ for core area; $z = -0.88$, $P = 0.38$ for core area percentage) nor do females overlap differently with males or females ($z = -0.43$, $P = 0.67$ for home range area; $z = 0.0$, $P = 1.0$ for home range percentage, $z = 0.0$, $P = 1.0$ for core area; $z = -0.21$, $P = 0.83$ for core area percentage).

DISCUSSION

The loss of 42% of the tagged birds (probably because of predation) is lower than other studies on ground-dwelling birds (which are common target species of several predators): 88% in adult-reintroduced Northern Bobwhites (*Colinus virginianus*; Oakley et al. 2002), 81% in Red-legged Partridge chicks (*Alectoris rufa*; Pérez et al. 2004) and 91% for the wild Spotted Nothura (Thompson and Carroll 2009).

The birds that died soon after being tagged had a lower body weight at the time of capture. Bird 75M did not live more than a month: it weighed 330 g and the tag represented 3.6% of its body mass at the time of capture (the highest percentage of all the tagged birds in this study). Bird 20F lived for 5 months and weighed 340 g (the tag represented 3.5% of its body mass). The weight of the birds that died later ranged from 420–505 g, unlike those that survived, whose body weight ranged from 510–740 g. Although some researchers failed to detect any effects caused by transmitters weighing less than 4% of body mass (Murray and Fuller 2000), and Barron et al. (2010) suggested little evidence of negative effects when tags exceeded 3%, it is important to consider a predation phenomenon linked to weakness or a lack of experience (if body mass is related to age).

The mean home range size (100% MCP) reported for the Ornate Tinamou in this study is approximately twice the highest home range values reported for other species in this family and approximately 20 times greater than the so-called 'nest and feeding territory' reported by Pearson and Pearson (1955) for the Ornate Tinamou. In another study that used radio-tracking technology for tinamous, Thompson and Carroll (2009) reported 100% MCP mean home range sizes from 16 ha (crop and grazing sites) to 19 ha (crop sites) for the Spotted Nothura. Although Thompson and Carroll (2009) did not report individual home ranges, they highlighted a great inter-individual variation, which is similar to our results for the Ornate Tinamou. Our minimum values of individual home range sizes of Ornate Tinamou correspond with those described for other tinamous in the literature.

However, the majority of the previous reports were conducted with direct or signal observations. For example, Schäfer (1954) used a hunting dog to assess home ranges and reported a very small territory of 0.1 ha for Highland Tinamou males and territories of 20 ha for the Gray Tinamou (*Tinamus tao*). Lancaster (1964a) reported home ranges between 17–24 ha for the Brushland Tinamou by detecting the individual songs of four males. The same author, using the same technique, reported home ranges between 11–19 ha for the

Red-legged Tinamou (*Crypturellus erythropus*; Lancaster 1964b).

We found a high percentage of overlap in home ranges and core areas; these values may be even higher, as only a small percentage of the population was tagged. A high proportion of overlap was reported for other tinamous. Lancaster (1964a) described an overlap in the home ranges of Brushland Tinamou males of approximately 75%, and similar findings for the Red-legged Tinamou (Lancaster 1964b).

The Ornate Tinamou adult individuals remained within their home ranges for a whole year, with no great movements. Therefore, individuals must be able to obtain resources within their home ranges, by taking advantage of both spatial (different habitat types on a small scale) and temporal (annual crop management) heterogeneity, which is closely associated with the generalist and opportunistic feeding behavior of this species (Garitano-Zavala et al. 2003).

Sentinel species provide useful data for understanding or predicting potential human health impacts from environmental contaminants (Stahl 1997). Wildlife species have a wide variation in distribution, and migratory, dietary and reproductive habits, which are fundamental factors when selecting a species as a sentinel organism (Fox 2001). The parameters related to home range size, residence overlap and dietary habits of the Ornate Tinamou show that individuals are at risk of coming into contact and ingesting the chemical hazards in polluted areas, and therefore it is possible to assume that the bio-accumulation patterns of chemical hazards are directly associated with the pollution characteristics of the area in which the individuals were captured. This highlights the usefulness of the Ornate Tinamou as a sentinel species for Andean mining activities, where pollutants such as trace metals can reach soils, and water from the tailing piles may contaminate the crops and water consumed by tinamous and humans (Garitano-Zavala et al. 2010).

From a cynegetic management point of view, our results suggest that adult individuals are sedentary. If residence in a particular area is maintained throughout all the bird's life, it is important to use caution when hunting activities are planned, because the recolonizing capacity of Ornate Tinamou adult individuals may be seriously limited. If this is the case, then local extinction would occur if hunting affected all of the individuals in an area. Moreover, the dynamics and dispersion capacity of juveniles need to be evaluated, because the great movements and premature deaths of some of the individuals we studied could be interpreted as sub-adult non-resident individuals not being established in a stable home range. Before planning sustainable cynegetic activities for this species, it is crucial to gain a better understanding of its recolonizing capacity from non-hunted areas.

ACKNOWLEDGMENTS

We thank E. Hug, P. Justiniano, P. Ortega and K. Olarte for their collaboration in the field, and two anonymous reviewers for their valuable comments to improve this paper. This research was conducted with the approval of the Dirección General de Biodiversidad y Áreas Protegidas (DGB-AP) of the Bolivian Government and the ''Comunidad Originaria de Qurpa.'' The study was funded by the Projects CGL2005-04772/B05 (Spanish Ministry of Science and Innovation) and GRC 2009SGR43 (Generalitat de Catalunya regional authority).

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