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NOTE AND COMMENT

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Effects of an earthquake on wildlife behavior: a case study of takin (*Budorcas taxicolor*) in Tangjiahe National Nature Reserve, China

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Abstract The question of whether large-scale disturbances, such as earthquakes, impact an animal's behavior significantly is an important question, but one that is difficult to answer due to the unpredictability of these types of events. Here, we collected 323 GPS locations of four takin (*Budorcas taxicolor tibetana*) in 13 days before and after a powerful (8.0 magnitude) earthquake on May 12, 2008 in Sichuan Province, China. The movement during this period was compared to that of three of the same animals during a corresponding period in 2009 (April 30 to May 25) and a slightly later 2009 period based on the start of migration (May 6 to May 31). We found that home ranges reduced in size during each study period, due to the migration process, but with no discernable differences due to the earthquake. The takin also showed the same pattern of elevation change and linear travel distance during 2008 and 2009, indicating no detectable effect of the earthquake on spatial behavior of takin. These findings add to our knowledge of how animals respond to catastrophic natural events in the wild.

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Introduction

Researchers have reported increased activity in captive animals before and after earthquakes (Shaw 1977; Buskirk et al. 1981; Mulilis and White 1986; Geller 1991; Ikeya et al. 1996; Lighton and Duncan 2005; Olson and Allen 2005). Field studies on primates during earthquakes and aftershocks also reported abnormal behavior and increased activity (Snarr 2005; Fujimoto and Hanamura 2008). The behavior of animals usually changed during an earthquake and/or aftershocks, but to date, no data on the movement of terrestrial animals near the epicenter of a major earthquake have been reported. We report on the behavioral response of a large ungulate whose seasonal migration along an altitudinal gradient (Histøl and Hjeljord 1993; Singer et al. 2000; Igota et al. 2004) coincided with a major earthquake and its aftershocks.

A powerful earthquake (8.0 magnitude) occurred on May 12, 2008 (14:28, UTC + 8, all subsequent references will be in local time) in Wenchuan, Sichuan, China (Fig. 1). By June 2008, it was estimated that over 45 million people had been affected (China Earthquake Administration 2008a). Moreover, the wild habitat of many animals, such as the giant panda (*Ailuropoda melanoleuca*) in the Minshan and Qionglai Mountains, was severely affected (Wang et al. 2008).

The takin (*Budorcas taxicolor*) is a large ungulate found in high-altitude forest and shares its habitat with the giant panda and golden monkey (*Rhinopithecus roxellanae*) in southwestern China. In the Minshan Mountains, takin make seasonal altitudinal migrations to obtain fresh food and prepare for breeding (Zeng et al. 2008, 2010). Their spring movement from lower (below 1,300 m) to higher elevation (above 2,000 m) occurs during the end of April to early June (Wei et al. 1991). The Wenchuan earthquake occurred during the

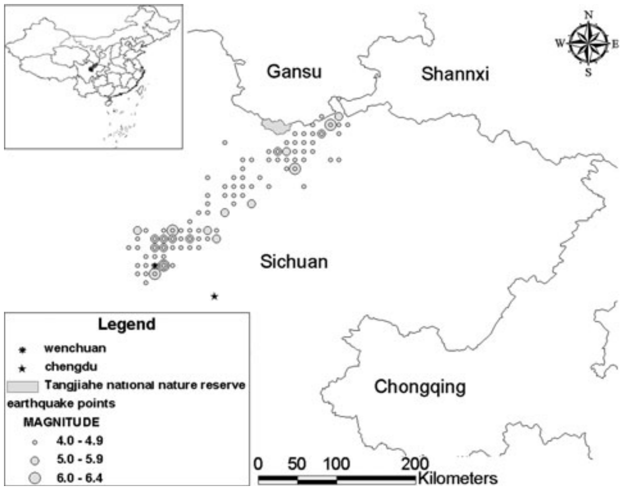

Fig. 1 A map of the area affected by the earthquake on May 12, 2008 with location and magnitude of aftershocks included (China Earthquake Administration 2008b)

period when takin were making their spring migration to higher elevations.

Based on previous reports that animals were more active immediately (either 1–2 days or several hours) prior to an impending earthquake (Shaw 1977; Buskirk et al. 1981; Mulilis and White 1986; Lighton and Duncan 2005) or during aftershocks (Snarr 2005; Fujimoto and Hanamura 2008), we considered the intensive aftershocks of the Wenchuan earthquake as a continued disturbance and hypothesized that the takin would be more active, as measured by daily travel distances and home range, following the earthquake and its attendant aftershocks. Increased activity would result in takin traveling longer daily distances and occupying a larger home range in the period after the earthquake (a period with significant aftershocks) when compared to their activity before the earthquake. With regard to elevation, we predicted that takin would be found at higher elevations after the earthquake because the earthquake occurred during the spring migration period, and their normal altitudinal migration, based on movement toward green alpine pastures (Zeng et al. 2010), would not be altered.

Materials and methods

Study area and animals

We conducted our research in the Tangjiahe National Nature Reserve, Sichuan Province. Tangjiahe is located at Qingchuan County in the northwestern edge of Sichuan Basin, on the Longmen seismic belt (Wang et al. 2008), which is about 200 km from the epicenter of the Wenchuan earthquake. Since October 2006, we have captured and collared eight takin, with six of the collars active when the earthquake occurred (May 12, 2008). Each animal was captured via a dart rifle, using an anesthetic cocktail consisting of 2 mg carfentanil citrate, 12 mg detomidine, and 280 mg ketamine per animal. After sedation, it took us an average of 30 min to find, check the animal, and apply the collar before applying the antidote. The reversing doses were 200 mg naltrexone, 1,200 mg tolazoline, and 25 mg atipamezole, given intramuscularly. The collar (model: GPS 4400 M, Lotek Wireless Inc.) weighed approximately 1,300 g (less than 1% of the mass of takin) and was programmed to record the location of the collared animal four times per day at 0:00, 7:00, 12:00, and 19:00 UTC (local time is UTC + 8). On the day of the earthquake, two of us were in the field and felt the ground quivering; steep slopes along the single road within the reserve experienced significant landslides and the air was filled with particles. Significant aftershocks were experienced at our field study for months following the earthquake (China Earthquake Administration 2008b). Fortunately, all six of the takin with functioning radio collars survived and five collars continued to accumulate positions, but one of them recorded, on average, less than one location per day.

We downloaded the GPS data in November 2008; four of the collars (on takin F1, F2, M1, and F3) each recorded more than 40 positions from April 30 to May 25, 2008. We downloaded the GPS again in September 2009 for three of the animals (F1, F2, and F3), and one animal (M1) was missing.

We used GPS locations of four collared takin (> 1 location per day) collected at the earthquake-stricken area from April 30 to May 25 to analyze movement responses to the earthquake in 2008. To assess whether the earthquake had acute effects on behavior, we divided our data into two phases, before (first phase 0001 hours April 30 to 0001 hours May 12) and after (second phase 0701 hours May 12 to 2001 hours May 25) the earthquake. The latter phase included a number of significant aftershocks (mean 13.84 aftershocks of ≥4.0 magnitude/day). The most serious aftershock of 6.4 magnitude occurred on May 25 (China Earthquake Administration 2008b).

We also compared 2008 data to 2009 in order to determine whether any differences we saw between the phases of the earthquake were more likely to be due to the earthquake or to the normal altitudinal migration occurring at this time of year. We chose two different sets of dates to define the study period in 2009. First we selected the same day as the quake the year earlier (12 May) and used data from 13 days before and after this date; this dataset is referred to as 2009a. We also used May 18 as the "earthquake date" and analyzed data from 13 days before and after this date; this dataset is referred to as 2009b. We chose this alternative observation period because the migration started later in 2009 compared to 2008.

Variables measured

We calculated the 100% minimum convex polygon (MCP) and the 95% kernel home range of each takin by using the Home Range Extension (Rodgers and Carr 1998) of ArcView GIS 3.3 (ESRI Inc. 2002) (Börger et al. 2006; Laver and Kelly 2008) based on the data collected from F1, F2, M1, and F3. In the Home Range Extension, we selected unit variance standardization, fixed smoothing, volume contours, and a raster resolution of 200 (which corresponded to a cell size of proximately 50 m). We also calculated daily travel distances using the linear distance between sequential GPS locations, and the elevation occupied by F2, M1, and F3, to represent movement of collared takin in the study period. F1 was excluded from daily linear traveling distances analysis since we did not obtain a sufficient number of locations for calculating daily linear traveling distances.

Analysis

We compared home range sizes, elevations, and daily linear traveling distances of collared takin between different phases (before and after) for each study period (2008, 2009a, and 2009b) using appropriate statistical methods. A Wilcoxon test on two related samples was employed to compare home ranges, while an independent samples Mann–Whitney *U* test was used to compare daily elevation change and daily travel distance comparisons for each animal. We investigated the possible effect of the earthquake on daily elevation change and daily travel distance using a BACI approach (Before-After-Control-Impact; Krebs 1999). We used a linear mixed-model analysis with the animal as a random factor and year (2008 vs. 2009a and 2008 vs. 2009b) and phase (before or after earthquake) as fixed factors to analyze daily elevation and mean daily linear travel distance in the study sample as a whole. All data analyses were conducted using SPSS 16.0 (SPSS Inc. 2007).

Results

We obtained 323 GPS locations of four takin during the 2008 study period (150 locations before and 173 locations after the earthquake), 246 GPS locations from three of the four collared takin in the 2009a period (107 locations before and 139 locations after), and 245 locations in the 2009b (115 locations before and 130 locations after) period (Table 1).

Home range

All four of the takin exhibited reduced their home ranges (100% MCP and 95% kernel, $z = -1.826$, $df = 3$, $p = 0.034$, one-tailed test) in 2008 after the earthquake, compared to the period before the earthquake (Table 1).

There was no significant change of home ranges in study period of 2009a and 2009b. Home ranges trended to be larger in the "after" period in 2009a (100% MCP and 95% kernel, $z = -1.604$, $df = 2$, $p = 0.055$, one-tailed test), but in 2009b 100% MCP home ranges trended to be smaller in the "after" period ($z = -1.604$, $df = 2$, $p = 0.055$, one-tailed test), then the 95% kernel analysis showed a different *p* value ($z = -0.535$, $df = 2$, $p = 0.297$, one-tailed test) (Table 1). The 95% kernel home ranges during the study period of 2008 are shown in Fig. 2.

Table 1 Home range sizes of collared takin in the 13 days before and after the Wenchuan earthquake in 2008 and in the corresponding period of year 2009

Code	Takin	Year	Phase[a]	Valid GPS records	100% MCP (km^2)	95% KDE (km^2)
F1	Adult female	2008	A	14	0.16	0.28
			B	30	0.03	0.05
		2009a	A	20	0.23	0.10
			B	37	0.24	0.24
		2009b	C	26	0.14	0.08
			D	33	0.06	0.09
F2	Adult female	2008	A	48	3.52	3.26
			B	51	2.73	2.83
		2009a	A	47	2.62	2.01
			B	52	3.35	4.01
		2009b	C	48	2.57	2.89
			D	48	2.08	3.12
F3	Adult female	2008	A	41	1.09	1.06
			B	46	0.4	0.54
		2009a	A	40	0.45	0.55
			B	50	0.57	0.25
		2009b	C	41	0.58	0.33
			D	49	0.28	0.27
M1	Adult male	2008	A	47	5.51	0.38
			B	46	0.23	0.29

The 2009 data were either divided on the same date as the quake in 2008 (2009a) or 1 week later based on the later start of the migration in 2009 (2009b)

[a] 2008 and 2009a: *A* April 30–May 12, *B* May 12–May 25; 2009b: *C* May 6–May 18; *D* May 18–May 31

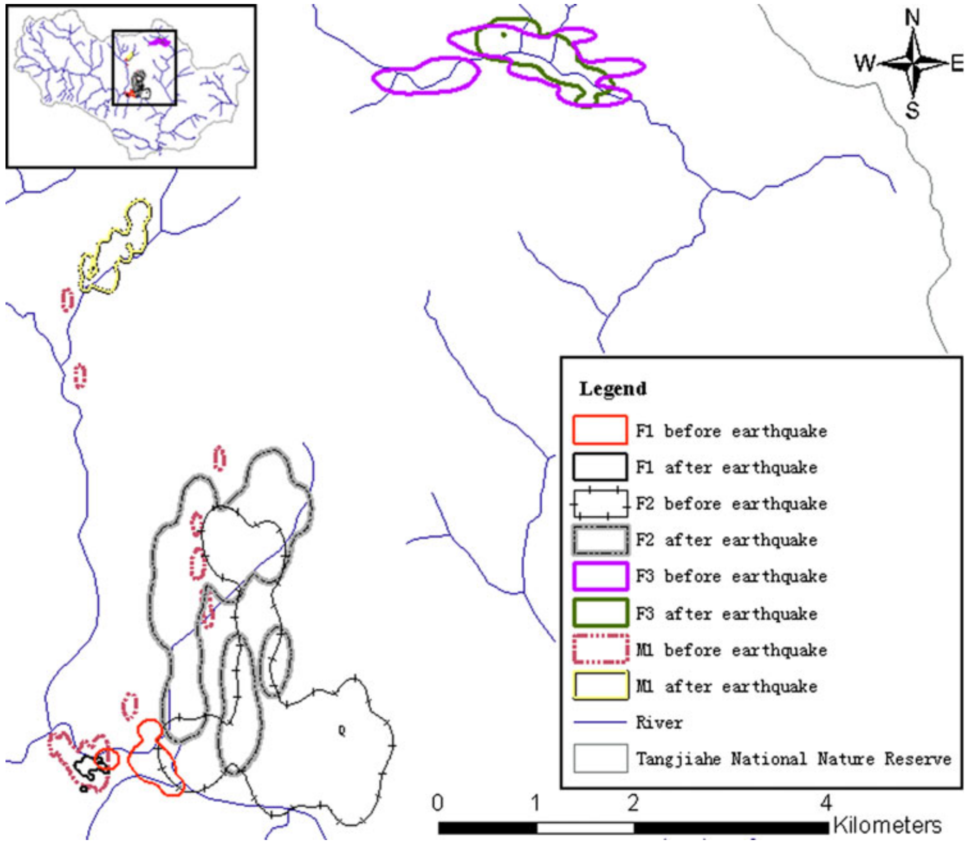

Fig. 2 The 95% kernel home ranges of four adult takin 13 days before earthquake and the 13 days after earthquake

Elevation change

Figure 3 shows the daily elevation change during the study period in 2008 and 2009. Takin F2 ($z = -2.932$, $p = 0.003$) and M1 ($z = -4.103$, $p < 0.001$) moved up to higher elevations after the earthquake in 2008, while F1 ($z = -0.334$, $p = 0.738$) and F3 ($z = -0.489$, $p = 0.625$) demonstrated no change in elevation throughout the study period. In 2009a, the three collared animals presented the same movement trend as they did the previous year in that F1 and F3 did not significantly change their elevation (F1, $z = -1.386$, $p = 0.166$; F3, $z = -1.389$, $p = 0.165$) and F2 moved to higher elevation ($z = -3.858$, $p < 0.001$). In the 2009b period, F1 did not significantly change her elevation ($z = -1.905$, $p = 0.057$) but F2 and F3 moved to higher elevation (F2, $z = -2.109$, $p = 0.035$; F3, $z = -3.600$, $p < 0.001$; Table 2).

In linear mixed-model analyses, there was no significant effect of year (2008 and 2009a), phase (before and after earthquake), or a year by phase interaction on daily elevation change (for year $df = 1$, $F = 0.186$, $p = 0.678$; for phase $df = 1$, $F = 4.005$, $p = 0.085$; and for interaction $df = 1$, $F = 0.101$, $p = 0.759$). When comparing 2008 to 2009b, there was no significant effect of year ($df = 1$, $F = 0.018$, $p = 0.896$), phase ($df = 1$, $F = 4.657$, $p = 0.067$) and interaction between the variables ($df = 1$, $F = 0.335$, $p = 0.580$) on elevation change.

Traveling distances

The linear traveling distance of three collared takin did not show a significant difference during the two periods in 2008 (F2: $z = -1.268$, $p = 0.205$, M1: $z = -1.828$, $p = 0.068$, and F3: $z = -1.705$, $p = 0.088$), in 2009a (F2: $z = -0.760$, $p = 0.447$, F3: $z = -0.914$, $p = 0.361$) or in 2009b (F2: $z = -1.058$, $p = 0.290$, F3: $z = -0.108$, $p = 0.914$; Table 2; Fig. 4). The linear mixed-effect model analysis did not detect significant effect of year (2008 and 2009a, $df = 1$, $F = 0.029$, $p = 0.872$), phase ($df = 1$, $F = 7.390$, $p = 0.053$), and a year by phase interaction ($df = 1$, $F = 0.388$, $p = 0.567$). In analyses of 2008 versus 2009b, there was no significant effect of year ($df = 1$, $F = 0.269$, $p = 0.630$), phase ($df = 1$, $F = 1.746$, $p = 0.257$), or the interaction term ($df = 1$, $F = 3.165$, $p = 0.150$) on linear travel distance.

Discussion

Normally, takin make two seasonal migrations over the annual cycle, in spring and fall (Zeng et al. 2008). With movement to the higher elevations in the spring migration period (Wei et al. 1991; Zeng et al. 2010), it is expected that they should cover a larger range, but once the takin have reached their summer ranges, the home range should be smaller. The collared takin trended to reducing their home ranges in the period immediately following the earthquake in study period of 2008 and 2009b; however their ranges trended to increasing size following the earthquake in the 2009a dataset.

Why did the takin decrease the size of their home ranges during the 2008 study period? Was the reduction due to the migration or to the effect of earthquake and aftershocks? A possible explanation is that the earthquake and aftershocks reduced the movements of takin, which resulted in smaller home range size. However, these observed changes in home range size may be based partially on differences in the timing of migration between the comparison years. F2 and F3 finished their migration around May 18, in 2009 (Fig. 3), while F2 and M1 arrived at higher elevation on May 11, 2008. By adjusting the 2009 observation period to May 6–May 31 (i.e., 2009b), and using the 100% MCP home range calculations, we found no difference in home range between the earthquake year and the subsequent year. This finding indicates that the observed changes in home range size during the earthquake period were affected by the migration rather than by the earthquake (Table 1).

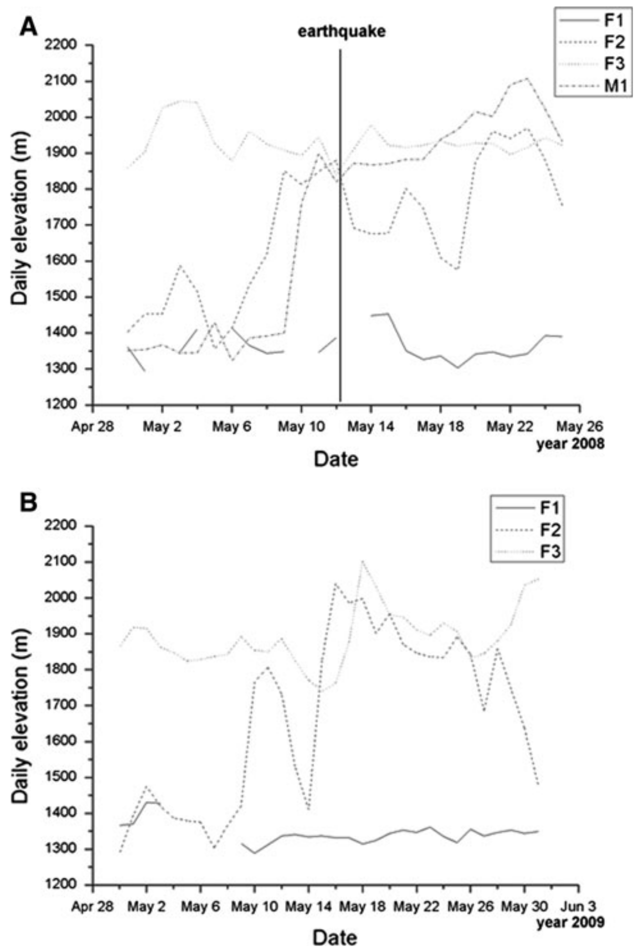

Fig. 3 The daily elevation change of collared takin: year 2008 (**a**), and year 2009 (**b**)

Many ungulate species gain access to more nutritious food by traveling along altitudinal gradients or moving to northern slopes in spring in the northern hemisphere (Wu et al. 1966; Wiersema 1984; Krasińska et al. 1987; Fryxell and Sinclair 1988; Mysterud et al. 2001; Sakuragi et al. 2003; Zeng et al. 2010), and the home range should be enlarged when the animals conduct these migratory movements (Endo and Doi 1996; Grund et al. 2002). Forage quality is usually better at higher elevation in the temperate region after the spring to summer transition (Albon and Langvatn 1992), and home ranges should be reduced upon arrival at summer pastures. Our data on home range support this pattern of large ranges during the migration and smaller home ranges once the animals reach the summer pastures. In the study period, two takin increased their elevation significantly after the earthquake in 2008, while the other two takin did not demonstrate a spring migration. We believe that the difference in spring migration pattern between the four takin was due to variability in their natural migration pattern rather than an effect of the earthquake. F2 and F1 showed the same spring migration pattern in 2009. F3 changed its elevation position significantly during the period of 2009 compared to 2008. Individual differences in migration pattern have been reported in moose (*Alces alces*; Demarchi 2003) mule deer (*Odocoileus hemionus*), and pronghorn (*Antilocapra americana*; Sawyer et al. 2005).

Table 2 Mean elevation (m) and daily linear distance (m) of collared takin before and after the earthquake (mean ± SE)

Takin	Year	Elevation			Daily linear distance		
		Before	After	*p*	Before	After	*p*
F1	2008	1,358.6 ± 12.2 (*n* = 9)	1,365.5 ± 12.7 (*n* = 13)	0.738	–	–	
	2009a	1,372.4 ± 18.6 (*n* = 9)	1,336.2 ± 3.4 (*n* = 14)	0.166	–	–	
	2009b	1,335.3 ± 11.1 (*n* = 9)	1,341.5 ± 3.8 (*n* = 14)	0.057	–	–	
F2	2008	1,570.6 ± 51.4 (*n* = 12)	1,788.6 ± 25.2 (*n* = 14)	0.003	1,115.7 ± 74.1 (*n* = 10)	973.0 ± 79.8 (*n* = 11)	0.205
	2009a	1,448.5 ± 47.8 (*n* = 12)	1,832.9 ± 46.7 (*n* = 14)	<0.001	1,211.6 ± 91.3 (*n* = 9)	1,053.0 ± 138.0 (*n* = 11)	0.447
	2009b	1,630.3 ± 74.7 (*n* = 12)	1,813.4 ± 36.2 (*n* = 14)	0.035	1,013.5 ± 135.2 (*n* = 8)	1,219.3 ± 128.9 (*n* = 9)	0.29
F3	2008	1,942.6 ± 18.3 (*n* = 12)	1,919.6 ± 8.0 (*n* = 14)	0.625	1,081.2 ± 164.1 (*n* = 5)	712.9 ± 83.2 (*n* = 7)	0.088
	2009a	1,861.8 ± 9.0 (*n* = 12)	1,896.5 ± 26.9 (*n* = 14)	0.165	744.3 ± 182.4 (*n* = 4)	609.3 ± 138.9 (*n* = 11)	0.361
	2009b	1,830.3 ± 17.2 (*n* = 12)	1,946.1 ± 21.5 (*n* = 14)	<0.001	739.5 ± 243.0 (*n* = 6)	620.0 ± 101.6 (*n* = 10)	0.914
M1	2008	1,445.8 ± 53.0 (*n* = 12)	1,947.9 ± 23.8 (*n* = 14)	<0.001	859.7 ± 184.0 (*n* = 9)	493.9 ± 56.6 (*n* = 8)	0.068

The nonparametric analysis: two-independent samples test with Mann–Whitney *U* test was used

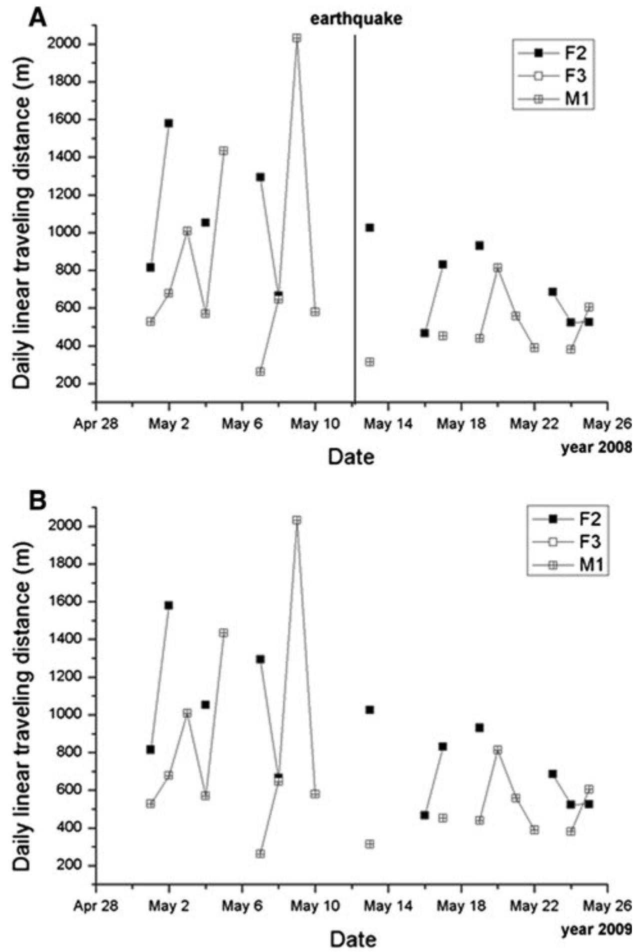

Fig. 4 The daily linear traveling distance change of collared takin: 2008 (**a**) and 2009 (**b**)

Previous work suggests that animals are generally more active following earthquakes (Shaw 1977; Buskirk et al. 1981; Mulilis and White 1986; Lighton and Duncan 2005). Our results did not support the conclusion of increased activity following earthquakes, as the linear traveling distance of collared takin did not change significantly following the earthquake.

Our sample size was small and so our conclusions must be viewed with caution. Based on the same pattern of elevation change and linear traveling distance during 2008 and 2009, we suggest no detectable effect of this earthquake on spatial behavior of takin.

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