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Site fidelity in the Sichuan Torrent Frog (*Amolops mantzorum*) in a montane region in western China

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Abstract. I used mark-recapture technique to estimate site fidelity in a subtropical high-elevation torrent frog (*Amolops mantzorum*) during the breeding season in Fengtongzhai National Nature Reserve in western China. I captured, measured, and individually marked 30 males and 15 females in 20 May 2007. I recorded each individual's initial positions using a Global Positioning System (GPS). For each night from 21 May to 10 June 2007, I recaptured the marked individuals and recorded capture points. The results showed that 16 males and 4 females were never recaptured in the field experiment. Most of the remaining individuals were recaptured only one time. Males and female were recaptured more than 2 and 8 times, respectively. Males and females were recaptured from subsequent positions as far apart as 55 m and 30 m, as close as 0.2 m and 0.1 m. Average neighbor distances on successive capture positions of males recaptured was 10.1 m, and that of females was 4.2 m, suggesting that there were significant difference in site fidelity between females and males. However, there was not significant average activity distance between the sexes. For females, small average activity areas were 10.9 ± 14.9 m^2.

Keywords. Site fidelity, *Amolops mantzorum*, mark-recapture.

Many anuran species exhibit territoriality, and the resource and predation defended varies with the behavioral strategy exhibited by an individual (Wells, 1977; Mathis et al., 1995; Bevier, 2006). The prolonged breeders may establish territories that include high-quality oviposition sites and low predator risks in breeding season (Wells, 1978). Resident male for several nights or weeks defend against conspecific intruders, a pattern that may increase terrestrial male's success in attracting females who lay eggs in his territory (Wells, 1978). Territories established by females can provide for high-quality oviposition environment and abundant food resources (Wells, 1977).

The genus *Amolops* consists of 18 ranid frogs adapted to running steam habitats in subtropical mountain regions in western China (Zhao and Adler, 1993; Liu et al., 2000).

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The Sichuan Torrent Frog *Amolops mantzorum* occurs in the montane regions of western Sichuan, southwestern Yunnan and southern Gansu, where it is found over a broad geographical area in terms of both latitude (between 23°57'N and 33°55'N) and elevation (1,000-3,800 m). The frogs prefer to stay on the surface of big rocks in the stream in night during the breeding season (Fei and Meng, 2005). Breeding season ranges from early May until late October, and frogs can be considered a prolonged breeder. In recent years, preliminary information on age structure and egg size of Sichuan torrent frog in the wild has been published (Fei and Meng, 2005; Liao and Lu, 2010a, b). So far, information about site fidelity during the breeding period is unavailable. In this study, I used mark-recapture method to measure the time recaptured of individuals and compare difference in site fidelity between males and females.

The study area is distributed in a mainly subtropical evergreen broadleaf forest in western China (30°33'N, 102°56'E, 1,700 m a.s.l.). It has the annual mean temperature ranging from 5.9 to 7.2 and the annual total precipitation ranging from 700 to 1,300 mm from 1976 to 2000. The vegetation covering the area is characterized by *Yushania brevipaniculata*, *Tetracentro sinense*, *Bashania faberi*, *Tsuga chinensis* (Liao and Lu, 2010b). The study site is a stream reach located in Dengchigou Protection Station of Fengtongzhai National Nature Reserve. The stream reach dimension (length) and widen where the study has been performed is 1000 and 20 meters, respectively.

I performed twenty-two sampling dates for 20 consecutive nights in spring 2007 (20 May-10 June). I captured *A. mantzorum* individuals by hand in night with the use of a 12 V flashlight when they stayed on emerged rocks in the stream. In the first sampling session I individually marked, in the field, each frog captured by clipping different toes of four limbs, I distinguished the sex (by nuptial pads on the first finger for male, eggs readily visible by the skin of the abdomen for female), and I measured the body length (from snout to vent, SVL) using a caliper to the nearest 0.1 mm. I recorded the GPS coordinates at the point of capture for each individual when the distance between successive individual captures was above 2 meters. We used tape measure to measure the distance of two successive points if it was less than two meters. In the subsequent sampling sessions I searched for individuals marked in the first session and I recorded each time, with the GPS, their position. In each sampling session, frogs were immediately released at the capture site after recording the coordinates of their position.

I calculated average distances between individuals in each of 20 nights and average distances between successive individual captures using RANGE V software. I used ArcView GIS 10.0 to calculate the activity distance and area for each male and female.

All statistical analyses were conducted using SPSS version 15.0 software (Statistical Product and Service Solutions Company, Chicago). I applied the Welch 's *t*-test to test differences in body size, activity distances and neighbor distances on successive capture points between males and females. Spearman correlation (r_s) was used for relationships between average neighbor distances on successive capture positions and the frog body size. The sampling efforts were comparable for all sampling dates. The values given are reported as mean ± SD and all statistical tests were two-tailed.

I captured and marked total of 30 males and 15 females in the first sampling. Average SVL differed significantly between males (53.9 ± 2.2 mm, range = 50.9-59.1 mm, n = 30) and females (67.8 ± 2.3 mm, range 62.9-71.1 mm, n = 15; Welch's *t*-test: t = 19.68, P < 0.001). Eleven females and fourteen males were recaptured at least once. Recaptured females (SVL = 68.0 ± 2.5 mm, range = 62.9-71.1 mm) were significantly larger than males (SVL = 54.2 ± 2.0 mm, range = 52.1-59.1 mm; Welch's *t*-test: $t = 3.98$, $P < 0.001$).

There were significant differences in the average of number of times I recaptured males and females (Fig. 1; Welch's *t*-test: $t = 3.03$, $P = 0.006$). I captured males and females an average of 1.1 ± 0.4 times and 2.8 ± 2.0 times, respectively. Of these recaptured individuals, 25 individuals (55.6%) were captured 1–8 times. Males and females were recaptured more than 2 and 8 times. Recapture rates in males and female were 46.7% and 73.3%.

Average distances between successive individual captures in males (10.1 ± 14.2 m, range = 0.2-30.0 m, n = 16) were significantly longer than those of females (4.2 ± 6.3 m, 10.1 ± 14.2 m, range = 0.2-30.0 m, n = 31; Welch's *t*-test: $t = 3.12$, $P = 0.002$). There was significant correlation between body size and Average distances between successive individual captures in females (Fig. 2; Spearman correlation analysis: $r_s = 0.77$, n = 11, P = 0.005), but not in males ($r_s = -0.26$, n = 14, P = 0.36). Average activity distances did not differ significantly between males and females (males, 11.6 ± 15.1 m; females, 1.9 ± 11.3 m; Welch's *t*-test: z = 0.84, P = 0.41).

Because all males recaptured did not exceed 2 numbers of times, I can not compute their activity areas. For females, average activity areas was 10.9 ± 14.9 m^2 (n = 5), ranging from 0.04 to 34.50 m^2.

Like most anurans (Monnet and Cherry, 2002), my results indicated that females had significant larger body size than males. The sexual size dimorphism in this frog may be attributed to the fact that natural selection favors females that have larger SVL to improve offspring size or fecundity (Kupfer, 2007). In my study, I found that toe-clipping did not

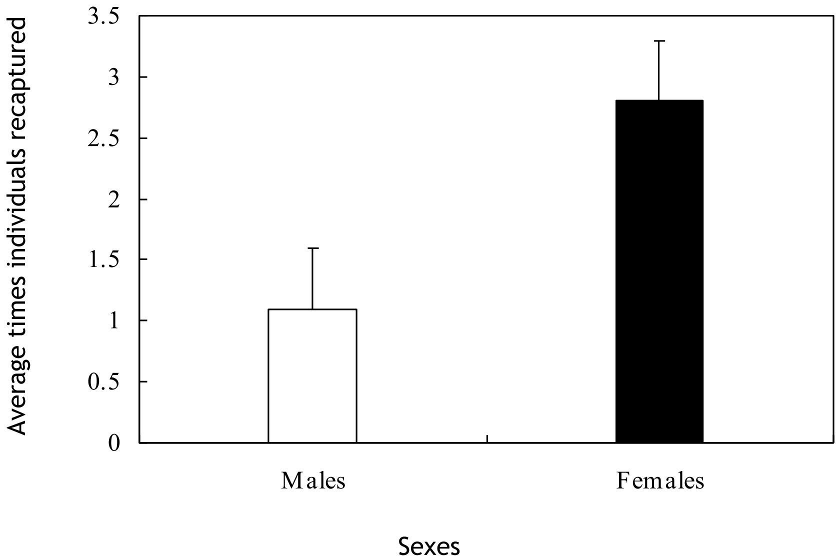

Fig. 1. The difference in average times between males and females recaptured of the Sichuan torrent frog (*Amolops mantzorum*) in a montane region in western China. Recaptured rate is shown as mean ± SD.

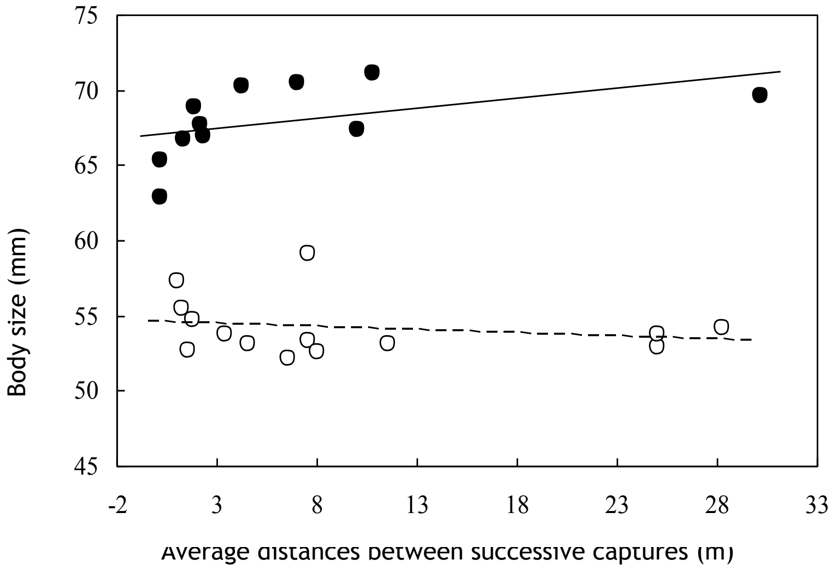

Fig. 2. The relationship between body size and average neighbor distances between successive capture positions of the Sichuan torrent frog (*Amolops mantzorum*) (male, open bars; female, close bars) in a montane region in western China. Body size in mm is shown as mean ± SD.

affect the survival and recapture rate, similar result has been reported in the frogs (Liao and Lu, 2010b).

Similar to male Mink Frog *Rana septentrionalis* (Bevier et al., 2006), male Sichuan torrent frog (*Amolops mantzorum*) was rarely recaptured at the same site, and exhibited relatively large nearest-neighbor distances on consecutive nights. This pattern suggests that males do not maintain long-term discrete territories to defend areas with resources important to females in a prolonged breeding period. In contrast, in may other frog species, males exhibit intense site fidelity, also for prolonged periods (Wells, 1977; Judge and Brooks, 2001; Gordon, 2004; reviewed in Wells, 2007). In contrast, in males of *A. mantzorum* I found rarely site fidelity since nearly half the marked male individuals were observed only once.

Compared to *A. mantzorum* males, females had relatively higher recapture rates. Differences in the capture rates between males and females may be due to behavioral differences related to the sex (i.e. different dispersion ability or similar behaviors involving moves). Females from my results had a smaller average distances between successive capture points than males, showing stronger site fidelity. In summarizing the reason that *A. mantzorum* females have small average distances between successive capture points, we make two possible points. Firstly, females returned to the same general site on consecutive nights in order to increase their chances of attracting and mating with a male due to a female-bias sex ratio in the site. Secondly, the small distances between rock-sites stopped on successive capture points suggested that females need defend high-quality areas with abundant food resources important to oviposition.

My data revealed that female body sizes in *A. mantzorum* were positively correlated with average neighbor distances between successive capture points. We speculated that larger females need larger area to obtain more food resources in reproduction than smaller ones maybe because they being larger are simply capable to cover larger distances. However, there was not significant correlation between male body size and average distances between successive individual captures, suggesting that both larger and small males do not defend areas with resources for females, but only search their chances to mate them. This is similar to previous study for site fidelity in *R. septentrionalis* (Bevier et al., 2006).

In my study, females had minimal average activity areas of 10.9 m^2 which also indicated their site fidelity. Similar results occurred in other anurans species. For example, *Rana clamitans* males defend relatively small areas that are up to 2.4 m^2 in dense vegetation and up to 9 m^2 in more open areas (Wells, 1977). Male territory size is approximately 3 m^2 in *Rana virgatipes* (Given, 1988). However, I did not obtain activity areas in males due to small samplings and shorter period studied. Therefore, deep study for male activity areas need be conducted in future.

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