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Telemetric Data Reveals Ecolgoically Adaptive Behavior of Captive Raised Chinese Giant Salamanders When Reintroduced into Their Native Habitat

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Abstract Little is known about the ecology of the Chinese Giant Salamander (*Andrias davidianus*), a critically endangered species. Such information is needed to make informed decisions concerning the conservation and management of this species. Four *A. davidianus* raised in a pool were released into their native habitat on 04 May 2005 and were subsequently radio-tracked for approximately 155–168 days. Following their release, the giant salamanders traveled upstream in search of suitable micro-habitats, and settled after 10 days. Later, a devastating summer flash flood destroyed the salamanders' dens, triggering another bout of habitat searching by the animals. Eventually, the salamanders settled in different sections of the stream where they remained until the end of the study. On average, each habitat searching endeavor took 7.5 days, during which a giant salamander explored a 310 m stretch of stream with a surface area of about 1157 m^2 and occupied 3.5 temporary dwellings. Each giant salamander spent an average of 144.5 days in semi-permanent micro-habitats, and occupied territories that had a mean size of 34.75 m^2. Our results indicate that the Chinese giant salamander responds to habitat disturbance by seeking new habitats upstream, both water temperature and water level affect the salamander's habitat searching activity, and the size of the salamander's semi-permanent territory is influenced by the size of the pool containing the animal's den.

Keywords amphibian, adaptive characteristics, micro-habitat selection, behavior, habitat selection, radio-tracking

1. Introduction

Basic ecological information is essential to design and implement conservation programs for rare and threatened species (Simberloff, 1988; Jiang *et al*., 1997). Furthermore, detailed information allows the development of more specific management measures, thus increasing the probability of achieving conservation success (Jiang, 2004).

Over the past couple decades, there has been a growing concern amongst ecologists and conservationists about the widespread decline of amphibian populations (Alford and Richards, 1999; Alford *et al*., 2001; Houlahan *et al*., 2000, 2001). The autecology of amphibians is vitally important for amphibian conservation and recovery efforts to succeed (Semlitsch, 2002), but is not well understood (Alford and Richards, 1999).

Andrias davidianus is a caudate amphibian endemic to China. Populations of this formerly abundant and widely distributing species have been severely depleted or extirpated by poaching and habitat loss (Zhang *et al*., 2002; Wang *et al*., 2004). The information on this critically endangered (Zhao, 1998) amphibian is qualitative at best and often anecdotal (Sichuan Changjiang Aquatic Resources Survey Group, 1974; Song, 1982; Li and Zhou, 1983; Hu, 1987; Fang, 1985; Ge and Zheng, 1992). This paucity of information is hampering conversation efforts aimed at conserving *A. davidianus* (Zhang *et al*., 2002; Wang *et al*., 2004; Zheng *et al*., 2005). To help fill in some of the many gaps in *A. davidianus* ecology, we

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conducted a study on the movements of radio-tagged Chinese giant salamanders in their natural range from May to October, 2005.

2. Methods

Two male (for short M1, M2) and two female (F1, F2) *A. davidianus* adults of varying sizes (72–81 cm long, weighing 1.35–4.20 kg) were tagged with radio transmitters and released in a stream pool (110°54.879′ E, 33°41.630′ N) in the Lushi Giant Salamander Reserve in Henan Province (110°35′-111°22′ E, 33°33′-34°23′ N) at dusk (1940 hours) on 04 May 2005. Established in 1982, this nature reserve is dedicated to the conservation of the Chinese salamander. Prior to the 1970s, when *A. davidianus* was still abundant, this area was a major center for trading wild salamanders; decimated by decades of illegal harvesting, wild salamanders became scarce by the 1990s and critically endangered when the new millennium dawned (Zheng *et al*., 2005). The salamanders used in this study were captured from local streams in 1996, and then raised in the Lushi County Giant Salamander Rearing Center. The release site was selected per IUCN/SSC Guidelines for Re-introduction (1995). Release sites in general must meet the following criteria: 1) salamander population density was high in the past; 2) the stream must have stable water sources so that it never dries up, must be long enough to provide the salamander with an adequate number of micro-habitats, and must have an abundant food supply; 3) anthropogenic disturbance is low, there must be no human dwellings along the stream. We investigated six streams and selected the Dachishuigou as the stream into which we would release the salamanders. This stream has an overall length of 8 km, and drops on average 30 m per km. The stream mouth is 20 m wide and 888 m above sea level. Boulders of varying sizes litter the streambed, forming many pools and crevices. Trees grow vigorously along the stream banks, shading the stream effectively.

Miniature radio transmitters (AVM G3-1V) were attached to the upper basal section of the tail following a previously described procedure (Blais, 1996), but the installing position of the transmitters was changed to avoid or reduce the possibility of their falling off. The transmitter measured 38×18×20 mm, and weighed approximately 16 g (0.38% to 1.19% of salamander body mass). The advertised battery life was 6 months. We used two VHF receivers (a Telonics TR-4 operating in the 162–166 MHz band, and an AVM LA12-Q operating in the 163–166 MHz band), of which each was fitted with a directional 3-element Yagi antenna, to track the salamanders in the wild. Radio signals of a submerged salamander could be detected within an approximately 100 m radius. The locations of the salamanders were pinpointed to within a meter via triangulation. We tracked these animals daily using radio telemetry every 2 hours, and checked their dens directly for 5–10 minutes every two days. During the study period, stream water level was measured daily at a pre-selected location (110°54.763′ E, 33°41.880′ N). At the end of this study on 18 October 2005, the salamanders were recaptured and returned to the rearing center.

The traveling distances of the salamanders were calculated assuming straight-line movements between successive fixes. The Minimum Convex Polygon (MCP) method was used to compute the areas traversed by these animals during their active periods.

3. Results

The salamanders were tracked for periods of 155 and 168 days; a total of 10 572 usable location fixes and 215 sightings were recorded (Table 1). Transmitter batteries went dead on two salamanders prematurely (M1 and F2). On 2 occasions, the transmitters dropped off from the animals (M2 and F1).

Table 1 Summary of tracking durations, usable fixes and sighting numbers

Salamander	Tracking duration (days)	Usable location fixes	Number of sightings
M1	168	2760	56
M2	155	2412	51
F1	160	2784	52
F2	166	2616	56

Following their release, the salamanders moved upstream, traveling at night and resting in temporary hiding places in water during the day. These types of upstream movements in search of an adequate micro-habitat took place twice (Period Ⅰ and Period Ⅱ, respectively) during this study. By 14 May, all salamanders had settled on a micro-habitat (Figure 1, Table 2). In early July, a summer flash flood forced the salamanders to take refuge in nearby shallow waters. Afterwards, the salamanders traveled upstream again, because their dens were destroyed by the flood (Figure 1, Table 2). They then settled in different sections of the stream where they remained until the end of this study (Table 3). The two periods of upstream movements were characterized by significant differences in environmental conditions (Table 4). The salamanders were markedly more active during the second period (Table 2). Residence was taken in underwater crevices that afforded good protection and easy access to air (Table 3). During the day, the salamanders rested in these hiding places, occasionally surfacing to breathe. At night they foraged for small aquatic animals within the stream pools where they resided (Figure 1, Table 3).

4. Discussion

Many intrinsic and external factors can influence habitat selection (Yan and Chen, 1998; Zhang and Hu, 2002). The results from our study indicates that the availability of suitable hiding places is of prime importance. This is not surprising since *Andrias davidianus*, a slumbering amphibian that is extremely vulnerable to predation by mountain carnivores such as *Vulpus vulpus*, *Mustela sibirica*, and *Arctonyx collaris*, spends most of its time hiding in its dens. The salamanders took residence in underwater crevices that afforded good cover and easy access to air. Top cover provided protection against predation and the sun; being in shallow, covered and slow moving water allows for easy access to the surface for

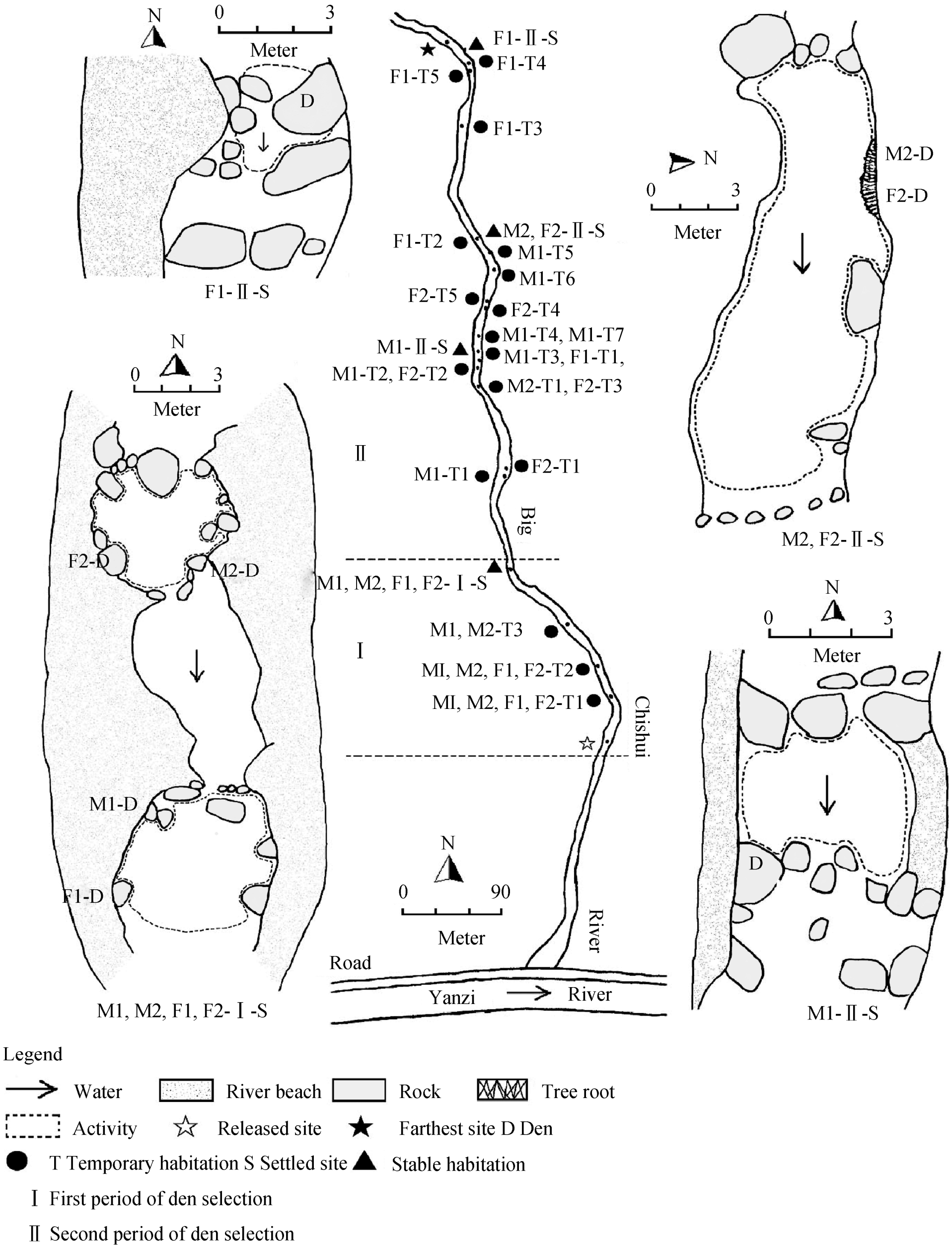

Figure 1 Micro-habitats and upstream movements of *Andrias davidianus*

Table 2 Statistics of upstream movements

Salamander		M1	M2	F1	F2	Average (M±SD)	Difference test (F)
Interval	I	May 04-10	May 04-12	May 04-14	May 04-14		
	II	Jul.10-18	Jul.10-13	Jul.10-20	Jul.10-15		
Duration (days)	I	6	8	10	10	8.5±1.91	2.33
	II	8	3	10	5	6.5±3.11	
Length of the stream stretch traversed (m)	I	204	210	204	210	207±3.46	14.26*
	II	346	390	554	361	412.75±95.92	
Stream gradient of the tretch traversed (‰)	I	24.5	23.81	24.5	23.81	24.16±0.40	9.41*
	II	15.9	17.95	21.66	15.23	17.69±2.89	
Area of the stream tretch traversed (m^2)	I	528	553	528	553	540.5±14.43	25.81**
	II	1524	1680	1524	2364	1173±400.80	
Number of stream pools explored	I	10	10	10	10	10±0.00	10.03*
	II	13	15	22	15	16.25±3.95	
Number of temporary hiding places	I	3	3	2	2	2.5±0.58	2.33
	II	7	1	5	5	4.25±2.22	

$P< 0.05$; ** $P< 0.01$

Table 3 Statistics of salamander habitations

Salamander		M1	M2	F1	F2
Interval	I	May 11-Jul.2	May 13-Jul.2	May 15-Jul.2	May 15-Jul.2
	II	Jul.19-Oct.18	Jul.14-Oct.18	Jul.21-Oct.18	Jul.16-Oct.18
Duration (days)	I	53	51	49	49
	II	92	98	90	96
Home range area (m^2)	I	25	19	25	19
	II	32	76	6	76
Top cover of den	I	Boulder	Boulder	Boulder	Boulder
	II	Boulder	Root cluster	Boulder	Root cluster
Substrate in-den	I	Sand	Sand	Sand	Sand
	II	Sand	Sand	Gravel	Sand

Table 4 Environmental conditions of the upstream movement periods

Interval	Water level (m)	Air temperature (℃)	Water temperature (℃)
May 04-May 14	0.26±0.02	13.9±5.3	16.7±2.1
July10-July 20	0.42±0.04	21.5±2.4	20.4±1.3
Difference test (F)	92.08*	18.20*	12.20*

$P< 0.01$

respiration while also being concealed from predators (Zheng *et al*., 2005). Sand or gravel substrate was preferred, presumably due to its modifiability-in this and earlier studies, giant salamanders were observed digging into sandy and gravelly stream beds, as well as ejecting sand and gravel from their dens. It nevertheless remains unknown why the salamanders inspected and then rejected many crevices that appeared to be of suitable size and adequate top cover. More research is required to decipher the salamander's micro-habitat selection criteria.

According to Shang (1998), the home-range size of an animal is determined by its sex and body size, food and refuge availability, as well as intra- and inter-specific competition. The results of our study suggest that the home-range size of *A. davidianus* may be little influenced by sex and body size. This conclusion however lacks validity due to the small sample size of this study; more research is required to either strengthen or disprove this hypothesis. The studies on home-range sizes of *Cryptobranchus alleganiensis*, a species closely related to *A. davidianus*, yielded similarly highly variable and often contradictory results (Hillis and Bellis, 1971; Coatney, 1982; Peterson and Wilkinson, 1996; Blais, 1996; Ball, 2001).

Both after their release and the destruction of their dens by the flash flood, the Chinese giant salamanders traveled upstream in search of a new micro-habitat. In other words, they responded to habitat disturbance by seeking new habitats upstream. This behavior is clearly adaptive. *A. davidianus* is a weak swimmer that inhabits mountain streams that are usually of high gradients and littered with boulders. While traveling downstream can easily be caught in rapids, smashed against boulders by currents, and injured or even killed. An *A. davidianus* moving upstream, on the other hand, they can effectively maintain their balance by grasping onto the stream bed, or even bypass the dangerous rapids by moving overland. Natural selection thus seems to favor *A. davidianus* individuals that responded to habitat disturbance by moving upstream.

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