

Behavioral Observations and Descriptions of the Endangered Knobby Newt *Tylototriton wenxianensis* and Their Application in Conservation

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Abstract.– *Tylototriton wenxianensis* is an endangered species at the status of VU. This paper introduces observations and studies including breeding, territorial, communication and antipredatory behaviors. The rules and mechanisms of the behaviors are recorded separately and described in the paper. Relationships between the behaviors and environment are also explained for the purpose of describing how the environment acted on the behaviors and how the behaviors adapted to the environment. The paper ends with conservation plans in connection with behavioral ecology: A) protect the particular habitat and avoid anthropogenic threats, B) artificial construction for natural migration and gene communication and C) artificial breeding and re-introduction into nature.

Keywords.– Observations, *Tylototriton wenxianensis*, behaviors, habitats, conservation.

Introduction

Tylototriton wenxianensis (Caudata: Salamandridae) is peculiar in China and poorly known. It is only found along the boundary between Gansu and Sichuan Province, narrowly distributed in Wenxian, Qingchuan and Pingwu (details see Table 1 and Fig. 1). It was defined as a threatened species with the status of VU (IUCN, 2006).

A representative of the Family Salamandridae, *T. wenxianensis* has rough and toxic skin with seasonal colors. The bilateral warts stay longitudinal and clustered in the same size and the boundaries between them are not clear enough. It is dark all over apart from the red-orange fingers, toes and the venter of the tail (Fei, 1993).

The newt lives in the heavily forested mountains at approximately 940 m. The adult is terricolous and usually wanders about the pool. It stays hidden under wet gravel or small muddy caves covered by fallen leaves in the daytime and appears at night for preying (Gong and Mou, 2006).

Behavioral studies on tailed amphibians have recently been reported. The studies were mainly focused in the following fields: breeding behaviors, including sexual recognition and sexual selection (Dawley, 1984), modes of courtship and mating (Arnold et al., 1972, 1977; Salthe, 1967, 1974), sperm competition (Arnold, 1977; Halliday, 1998; Massey, 1988; Sparreboom, 1995; Verrell et al., 1998), reproductive behavior (Fang, 1984; Harris et al., 2002; Park et al., 2000), parental care (Cramp, 1995; Nussbaum, 1985; Peterson, 2000), evolution of reproduction (Arnold, 1977; Veith, 1998; Verrell and Krenz, 1998,); migratory behavior (Arntzen, 2002;

Douglas, 1979; Griffiths, 1996; Serbiolova, 1995; Twitty, 1966); territorial behavior (Mathis, 1991; Mathis et al., 1998; Mathis et al., 2000; Simons et al., 1997); communications (Holliday, 1997; Houck, 1988; Houck and Sever, 1994; Rollmann, 1999; Verrell, 1989, 1989a,); antipredatory behavior (Brodie, 1990; Graves and Quinn, 2000; Maerz et al., 2001; Sih et al., 2000, 2003; Storer and Sih, 1998; Sullivan, 2002; Woody and Mathis, 1997). All the above provide a source of reference for the behavioral study on *T. wenxianensis*.

Methods

Migratory behavior.– We chose the habitat in Qingchuan as the site to observe, where a large population was found (Gong and Mou, 2006). The newts are not active year round except for the breeding season, so their migratory behaviours seem quite obvious and clear. We



Figure 1. Location of the habitats and observation sites.

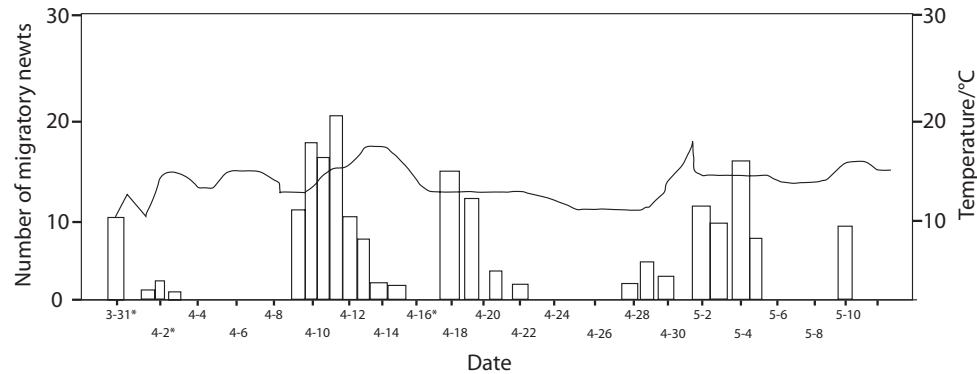


Figure 2. Reproductive migration of *Tylototriton wenxianensis*. The polyline represents temperature, columns represent number of the migratory newts and “*” rainy days.

made continuous observations when they migrated for breeding towards the pools nearby. We marked each migratory group with varisized loops and observed by radio tracking and GPS. Finally we made records of the time, route length, size of groups and sex ratio in the migration.

Reproductive behavior.- Reproductive behaviors included mating and spawning. We observed the course and took down the data of sex ratio, time, environment and quantity of the spawns etc.

Communication.- Communication happens along with courtship. We tried to understand how the newts communicate with each other and why. The communications included chemical signals and body-contacts (Jiang, 2004). Mechanisms of chemical signals from glands are expected to be understood through dissection. Types of the body-contacts and their effects on courtship were studied.

Territorial behaviors.- We measured the size of the territory occupied by 6 female newts and size of the tails and bodies in contrast. Aggressive behaviors related to the available prey in the environment were also observed. Relationships between the data and phenomenon were discussed and concluded.

Antipredatory behavior.- The newts were less aggressive without structures for aggressivity (Jiang, 2004).

They moved too slowly to escape attacks from enemies and to defend themselves. We made some model enemies and demonstrated the predation and antipredatory behaviors artificially.

Results and Analysis

Behaviors.- We made continuous observations on the migratory behaviors and found 186 adults including 170 females and only 16 males, the ratio was 170:16 (♀:♂) = 10.625:1. Breeding lasted from early April to late May with a peak from April 8th to May 6th. The average temperature was $15.5 \pm 4^\circ\text{C}$ (Fig. 2).

Like many other newts, *T. wenxianensis* does not seem to have significant secondary sexual characters. It distinguishes and selects the opposite sex primarily by sight and sense of smell. The male seemed more active. It courted the female by wagging its tail and dancing round. Meanwhile, the female was secreting chemicals and emitting a strong smell to attract the male. Soon the male bit the female on the tail (or hind limb), then they circled around both with their tails wagging (Fig. 3). Experiments show that the male prefers to choose a bigger one with more ovums and a stronger smell.

Mating did not accompany spawning in the meantime. It was the female that selected where to spawn. The male moved to the pool and settled down earlier than the female. However, the female left soon after spawning, while the male stayed until the end of the

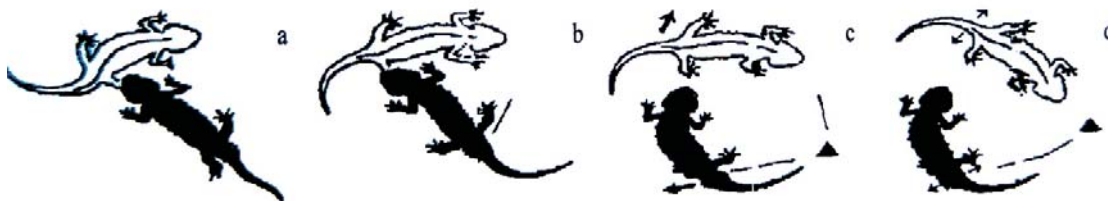


Figure 3. Model of mating behavior. Shows the male (black) wagging its tail and dancing round.

Table 1. Distribution and flora of *T. wenxianensis* along the boundary between Gansu and Sichuan Province.

Province	City	Country (town), county	Village	Latitude and longitude	Altitude (m)	Flora
Gansu	Longnan	Bikou, Wenxian	Bifenggou	103.7°E 33.95°N	927	semitropics
Gansu	Longnan	Liziba, Wenxian	Moziping	104.6°E 33.2°N	940	semitropics- intersemitropics
Gansu	Longnan	Liziba, Wenxian	Hanjialiang	104.4°E 33.1°N	1100	semitropics- intersemitropics
Sichuan	Guangyuan	Daba, Qingchuan	Wuxing	105.1°E 32.5°N	1160	semitropics- intersemitropics
Sichuan	Guangyuan	Daba, Qingchuan	Dawuji	105.1°E 32.46°N	998	intersemitropics
Sichuan	Guangyuan	Daba, Qingchuan	Laowuji	105°E 32.68°N	1092	semitropics- intersemitropics
Sichuan	Guangyuan	Daba, Qingchuan	Baishuling	105.14°E 32.32°N	1210	intersemitropics
Sichuan	Mianyang	Shuitian, Pingwu	Dafenling	104.23°E 32.58°N	1134	semitropics- intersemitropics
Sichuan	Mianyang	Bazi, Pingwu	Yinshanli	104.3°E 32.44°N	962	intersemitropics
Sichuan	Mianyang	Bazi, Pingwu	Miaoshanli	104.34°E 32.45°N	970	intersemitropics

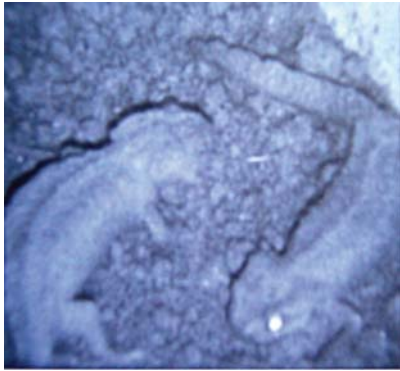


Figure 4. The sperm transmission. Swells show the colloidal secretion.

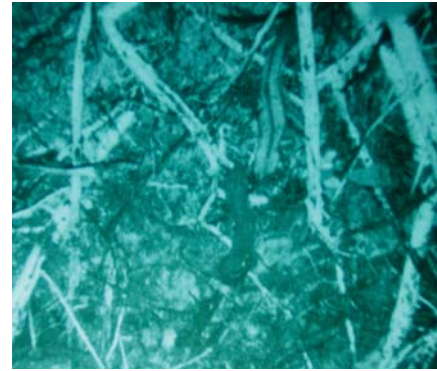


Figure 5. The courtship behavior. Shows the transmission of pheromones in the fantail.

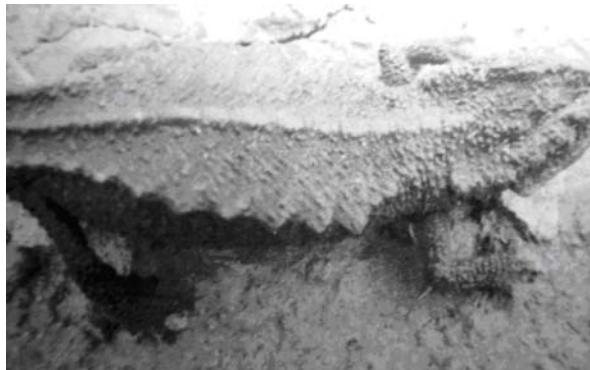


Figure 6. Rigid body: the reaction to anti-predator. Shows ribs jutting through the side warts.



Figure 7. The raised tail and warning color on the ventral surface of the tail.



Figure 8. The protuberant glands and warning color on the back. Shows harmful and toxic skin secretion, glandiform warts, spine glands, caudal glands, glandiform warts, spine glands, caudal glands, tergal glands, etc.



Figure 9. Playing dead. Shows the newts played dead with upward bottom and rigid body.

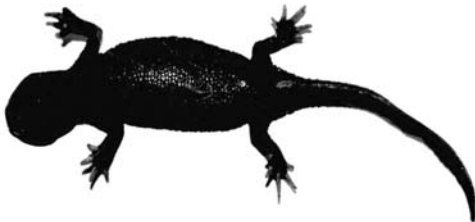


Figure 10. Mimicry: newt playing dead, with venter upward and body rigid.



Figure 11. The breeding pool (after spawning). Vicinity of Wuxing Village, Sichuan Province, southwest China.

Table 2. Relation between spawning territory, food and size of six female newts.

No.	Areas of spawning territory (m ²)	Percent of total (%)	TL (mm)	SVL (mm)	Food environment
1♀	0.64	10.39	58	71	poor
2♀	0.81	13.15	59.2	72.2	poor
3♀	0.55	8.93	55.7	70.1	poor
4♀	1.26	20.45	65.9	73.2	medium
5♀	2.3	37.34	67.4	74.6	high
6♀	0.6	9.74	56.1	71.4	poor

Table 3. The antipredatory behaviors of *T. wenxianensis*, grouped by different types. The observations were made in the field and in artificial conditions. a. harmful skin secretion; b. toxic skin secretion; c. parotids; d. glandiform warts; e. spine glands; f. caudal glands; g. tergal glands; h. tergal colors; i. ventral colors; j. rigid body; k. roll of body; l. exposed abdomen; m. raised tail; n. raised jaw; o. arched body; p. larger head; q. swagging tail; r. curved forehead; s. extended nerve.

	Imitative						Warning		Warning postures									Particular	
Types	toxicant body						colors											skeleton	
No.	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s

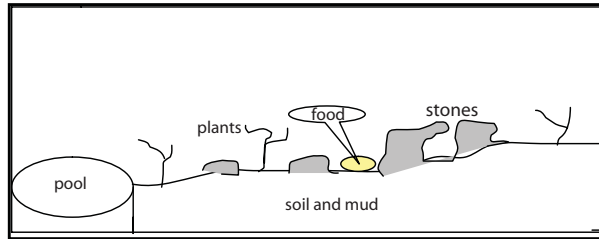


Figure 12. The artificial breeding box made of glass, 110 × 40 × 60 cm (lateral view). Shows the constitution and features of the breeding ecotope under artificial control.

breeding season. The analysis from Douglas (1979): First, to choose the optimum condition for spawning and to reduce risks in breeding migration; Second, to control the male genotype effectively through sexual selection.

Mating behavior happened on land, while spawning underwater. We analyzed the reason: the adult newt mainly lives a terricolous life. Sometimes it approaches the pools or streams for food. The observations on the behaviors in captivity indicate that the adults needed almost no water unless they felt too dry. They had adapted to the climate overland. In addition, in reproductive seasons, inorganic conditions overland near the pools may help them to secrete pheromones and sex hormones which could be significantly reduced underwater.

The newt took no attack on its kin, but became quite different towards non-related individuals. The newt recognized its kin through chemical signals. In the hot summer, the adult admitted the posterity into its territory sometimes and food became insufficient. Occupying territory usually accompanied attacks and fights. That depended on food quantity, size of body and environment (Table 2). The newt with longer tail and body occupied larger territory, closely related to the food quantity.

Communications were driven mainly by chemical signals and body contact. Chemical signals are necessary for the accurate and regular courtship behavior. The newts distinguished the sex and attracted each other by transmission of pheromones (Fig. 4) and secretion of hormones (Fig. 5), which later brought about the mating behavior.

Body contact was also important, particularly in

breeding behavior. Tactile signals were transmitted through touch on the mouth, collisions and friction between bodies.

In the long course of evolution, series of antipredatory behaviors had formed against captures, such as escapes, cryptic coloration, rigid body (Fig. 6), aposematic coloration (Fig. 7, Fig. 8), camouflage (Fig. 9), warning postures (Fig. 7), imitative toxicants, particular skeletal adaptations (Fig. 6), chemical defenses and playing dead (Fig. 10) etc. (Table 3).

Relationship between the behaviors and environment.-

The female finished spawning in a short time without male involved. Spawning lasted 2–3 days smoothly in rainy seasons without interference. They got to the spawning pools no sooner than they selected the proper sites. Spawning began one day later. The female spawned one a time lasting half a hour, and the whole course 5–6 hours. The course maintained a even pace slowly without a peak.

In Qingchuan, three pools were found with female newts and a mass of spawn. The three conditions for spawning sites were: A) ground covered with plants (the plants may be divided into three layers: the upper consisting of tall sparse laurisilvae, bushes in the middle and wet weeds at the bottom), B) spawning sites with semi-permanent pools, and the water soaked out after rain, C) it chose a mesa with loose soil as the spawning site on the hillside, covered by fallen leaves (Fig. 11).

The newt preyed mainly on insects, earthworms and snails. Like other amphibians, it stayed hidden in the day and preyed in the night. The behaviors changed sensitively with the temperature and sunlight.

In summers, plants flourished and numerous insects appeared, when the newt acts frequently. After thunderstorms, earthworms come out from the soil and supply food to the newts. In winter, the newts have to hibernate in response to the lack of food and low temperature.

Conservation plans.-

(1) *Protect the particular habitat and avoid anthropogenic threats.*

•Figure 10 shows the particular breeding habitat. The newts enter the pools and ground nearby only in

Table 4. Relationship between the conditions and hatching rate under artificial control.

No.	Temperature (°C)	Relative humidity (%)	Water pH*	Sunlight period (hour/day)	Incubation period (day)	No. of larvae	No. that hatched out	Hatching rate (%)
1	5~15	30~40	5.2	0.5	32	40	5	12.5
2	10~20	40~50	5.4	2	28	50	11	22
3	15~25	50~60	5.6	3	23	45	28	62.2
4	20~30	60~70	6	1.5	20	52	40	76.9

*Huang (2007) reported that pH 5.2–6.0 was most suitable for the development of larvae.

reproductive seasons, so it is of great significance to protect the similar pools. The pools were more or less 50 cm deep, 10 m² in size and at an elevation of 1000 m. Pieces of rocks piled around. Soil and mud around the pool was covered densely by rotted leaves. The vegetation nearby were mainly made up of shrubs and arbors (see Table 1).

Human activities, especially farming and poaching severely threatens breeding. Recommendations about plans to avoid these threats: A) build up fences around the mating sites and breeding pools to prevent the natural enemies and poachers from breaking in, B) reduce farming and grazing by livestock, especially around irrigation water from the pools, C) make (and enforce) laws to punish poachers.

(2) Artificial construction for natural migration and gene communication.

- Protect the whole habitat and ensure the natural migratory behavior. The migratory routes are usually blocked by farmland etc., so it may help keep the proper migration to build up artificial passages across the farmland.

Connect the adjacent pools by building canals as much as possible in order to ensure the communication of gene from different populations, especially from breeding groups. The measure may help avoid inbreeding depression and loss of genetic diversity in a small population and also help with evolution of the species.

(3) Artificial breeding and re-introduction into nature

- In view of the high sex ratio ($\text{♀}:\text{♂} = 10.625:1$ on average, $n = 186$) in the breeding season and the low rate of hatchability (46.54%; $n = 1272$) in nature, it is quite feasible to increase the hatching rate and reduce the sperm competition between the males in artificial conditions. We directly gathered the females and eugenic males with longer bodies (longer tails and bodies seem dominant in the sex competition apt to survive under natural selection (Jiang, 2004) and higher sperm density, and also keep the sex ratio at 1:1 in a artificial glass box (Fig. 12) to avoid competition and injury as well as to ensure high-quality inheritance.

Studies showed that factors influencing the hatching rate were natural enemies (such as snakes), climate changes and pollution (Tian et al., 1997). It is an effective approach to raising the survival rate and enlarging the population by hatching out the larvae in artificial conditions and re-introducing them into nature. The conditions include temperature, humidity, sunlight period and pH of water etc. (Table 4). Re-introduce the

juveniles into nature when they complete metamorphosis and get ready to land.

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