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The ecological specialist, *Thermophis baileyi* (Wall, 1907) – new records, distribution and biogeographic conclusions

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ABSTRACT – *Thermophis baileyi* (Wall, 1907) is a small montane colubrid snake, endemic to the Tibetan Plateau with unknown distribution. The species has previously been recorded from only three sites. We aimed to provide new records and to gather the baseline information on ecology and biogeography necessary to understand its origin and evolutionary history. Data were collected on several expeditions between 1999 and 2006 in Tibet (A.R., China). We surveyed selected locations that offered suitable habitat conditions for *T. baileyi* and determined every position using GPS. A map of hot-spring distribution on the plateau was then superimposed on these records. We report 13 new localities for *T. baileyi*, which is known only from hot-spring areas and has probably the highest altitudinal distribution among all reptiles, ranging from 3600 to 4900 m asl. The new localities extend the known range of the species considerably. Although *T. baileyi* is rare in Tibet as a whole, it seems locally common at selective sites; these populations may be relatively small and isolated. We infer that *T. baileyi* found glacial refugia in hot-spring locations during the uplift of the Tibetan Plateau and cooler periods of the ice ages. Owing to the availability of suitable habitats and high density of hot springs in China, a more extensive distribution in Sichuan and even in the northern parts of Yunnan seems likely. Because of its restricted wider distribution, and specific habitat preferences, we emphasize the need for populational and phylogenetic studies on *T. baileyi*, particularly with respect to continuing habitat destruction in the region.

THERMOPHIS baileyi (Wall, 1907), the Tibetan hot-spring snake (Hot-spring keel-back, Bailey's snake; type species: *Tropidonotus* (= *Natrix*) *baileyi*, F. Wall, 1907 by monotypy) has one of the highest known altitudinal distributions outside the tropics of any species of reptiles. This non-venomous colubrid snake (subfamily Xenodontinae, incertae sedis; Malnate, 1953; Lawson *et al.*, 2005) is known only from Tibet AR (Xizang), and there is very little information regarding details of its distribution (see cover illustration). It was recorded in Tibet for the first time in 1907 by Wall near Gyantze at 4300 m asl (no exact coordinates available) and reported from the Yangbajain hot-spring area (Loc. 11; Table 1) in 1990 and 1991 by Macey and Papenfuss (California Academy of Science, online collection catalogue, http://www.calacademy.org). In 1993, Papenfuss collected 11 specimens near Maizhokunggar (c. 70 km northeast of Lhasa) for the Museum of Vertebrate Zoology, Berkeley. Apart from the record at Yangbajain, no other records provide detailed coordinates.

The snake had previously been found only at high-altitude geothermic locations, where it occurs mainly in habitats associated with thermal springs close to rivers. Despite being listed as a rare species on the IUCN Red List, almost nothing is

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known about its ecology, life history and distribution except for some notes about threats at the Tibetan Plateau.

Here we present new distribution records and information about the habitat requirements of *T. baileyi* in Tibet, which seem to be especially interesting with respect to the glacial history of the plateau.

MATERIAL AND METHODS

Data on the distribution and habitats of the hot-spring snake were gathered during several expeditions between 1999 and 2006. Areas offering suitable living conditions for *T. baileyi* were surveyed based on recent sightings reported by local Tibetans. Most sites were visited at least twice; those with particularly many references were checked more frequently. Occupied sites were checked annually. Every location was specified by GPS coordinates. The snakes were captured by hand and a set of standard measurements was taken for every individual. In addition, several environmental parameters were recorded (ground and water temperatures, humidity).

RESULTS

We recorded the snake in 14 of more than 25 surveyed sites at high altitudes between 3600m and 4900m asl in the central part of the Tibetan

Figure 1. Known distribution of *Thermophis baileyi* (Wall, 1907) and hot spring locations in Tibet (Xizang) province.

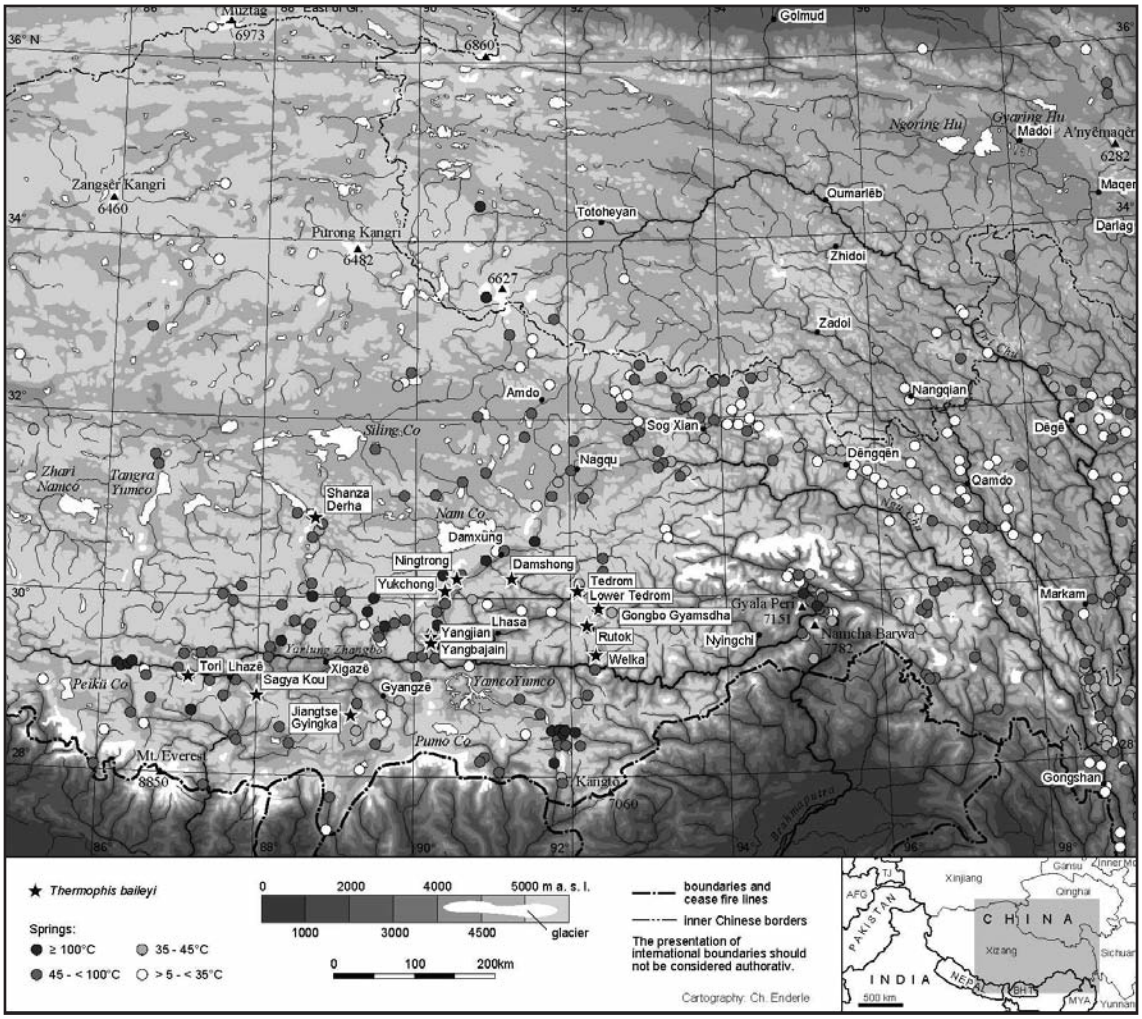

Figure 2. Typical habitat of *T. baileyi* (Yangbajain, AR Tibet). © S. Hofmann.

Plateau (Fig. 1, Table 1). Considering all these records, *T. baileyi* is known from *c.* 28°70' to 30°90'S and 87°12' to 92°14'E. The wide range of vegetation types surrounding the hot springs covers potential natural juniper forests, alpine dwarf shrublands, high alpine *Cyperaceae* mats and open scree vegetation (Figure 2).

To estimate the area in which *T. baileyi* might occur with relatively high probability, we overlaid our records with the distribution of hot springs (Chinese Academy of Sciences, 1990) using the computer programs Mapinfo vers. 7.5 (Mapinfo, New York) and ArcView vers. 3.2 (ESRI). Our results indicate that *T. baileyi* is relatively sparsely dispersed on the plateau and is probably more abundant in the eastern and central parts. If suitable habitats are available, it might also occur in hot springs in Sichuan and probably even in the northern parts of Yunnan.

The populations in Tibet appear to be more or less isolated from each other. As it is assumed that the snakes disperse only over short distances, we plan to track several adult individuals in spring 2007 to obtain specific information about their dispersal capacity.

Wall (1907) noted that *T. baileyi* "can be obtained in winter and summer alike", which seems doubtful if only because of the fact that food is very limited in winter. Local residents we spoke to all said that they had never seen a snake in winter time. At the type locality, the mean monthly temperature between November and February remains below 0°C and the mean minimum temperature of the coldest month is –14.5°C (data from the Meteor. Service China, as cited in Miehe *et al*., 2001). We infer that the seasonal activity period of *T. baileyi* thus begins between mid-April and May and extends until September or October.

We found *T. baileyi* in the vicinity of hot springs where they basked on the warmed up ground between rocks or along river banks. They were particularly active after rain. In contrast to Wall (1907), who stated that *Thermophis* "are reported

not to enter the water", some individuals were observed in the warm pools of hot springs and in adjacent rivers.

The water temperatures of the hot springs were relatively constant over the season and ranged from 29 to 33°C. River temperatures were much lower (8–11°C) and did not vary during a given day. At ground level, temperatures rose to 35°C as early as March (depending on solar radiation and ambient temperature).

Thermophis baileyi feeds primarily on metamorphs of the widely distributed *Nanorana parkeri* (synonym: *Altirana* Stejneger, 1927) and fishes of the genus *Schizopygopsis* (Tsering Dorge *et al*., pers. obs.); in turn it is preyed on by raptors such as buzzards (*Buteo hemilasius* and *B. buteo*), and the Tibetan sand fox (*Vulpes ferrilata*).

Ref. no.	Hot spring name	Latitude	Longitude	Alt. (m)
1	Shanza Derha	30°90'	88°70'	4680
2	Yukchong	30°09'	90°39'	4891
3	Ningtrong	30°23'	90°54'	4250
4	Damshong	30°23'	91°25'	4260
5	Terdrom	30°09'	92°09'	4412
6	Lower Tedrom	30°06'	92°10'	4401
7	Gongbo Gyamsdha	29°89'	92°36'	4470
8	Rutok	29°70'	92°21'	4359
9	Welka	29°37'	92°32'	3600
10	Yangjian	29°58'	90°21'	4410
11*	Yangbajain	29°51'	90°21'	4395
12	Jiangtse Gyingka	28°70'	89°20'	4200
13	Sagya Kou	28°90'	88°00'	4320
14	Tori	29°09'	87°12'	4120

Table 1. Geographic coordinates of the new records of *Thermophis baileyi* (Wall, 1907). To avoid adverse effects on these sites caused by private or commercial collectors, coordinates are given only with a precision of 0.1d. *Site "11" was first recorded by Macey and Papenfuss in 1990 (California Academy of Sciences, catalog number CAS 177878, http://calacademy.org).

DISCUSSION

With elevational records of up to 4900 m asl, *T. baileyi* achieves the world's highest altitude distribution among all snakes. The only other snake species with comparable altitudinal ranges are the Himalayan pit viper (*Gloydius himalayanus*; Günther, 1864) found in Pakistan, India and parts of Nepal at 1500-3050 m altitude (Khan *et al.,* 1986; McDiarmid *et al.,* 1999) and some small montane rattlesnakes of the genus *Crotalus* (*C. tancitarensis*, *C. triseriatus*; Alvarado-Díaz & Campbell, 2004), which live at elevations up to 3700 m on the Mexican Plateau and associated highlands. Some lizards of the genus *Sceloporus* and *Phrynosoma* reach elevations above 3500 m (Hodges, 2004) and several *Liolaemus* species occur even up to 5000m (Andrews, 1998). The Himalayan agama *Phrynocephalus theobaldi* is common in the alpine steppe of the Tibetan central highland in 4750 m and "may be found as high as seventeen thousand feet" (Schaller, 1997).

Species living at high elevations must be able to cope with strong winds, cold temperatures and desiccation, since rainfall is low and what little there is drains away quickly. Only a few of the hot springs on the Tibetan Plateau seem to provide suitable optimal habitat for the snakes in terms of food conditions and appropriate holes for refuge. The limiting habitat factor appears to be the existence of a stream or river beside the hot spring.

Because of its adaption to exceptional high-altitudes, the distribution and phylogeographic evolution of *Thermophis baileyi* might reflect the climatologic effects of the uplift of the Tibetan Plateau and the glacier extension of the last ice age. Neither of these environmental impacts is well understood. There is geological evidence that the hot springs listed in Table 1 were not covered by an ice sheet during the Last Glacial Maximum (e.g. Zhang & Li, 2002). The question of when the uplift of the Tibetan Plateau reached altitudes hostile to snakes that did not live near hot springs is still in dispute. Rowley and Currie (2006) give a late Eocene to Miocene age of altitudes more than 4000 m since the last 35 million years for the central Tibetan highlands, whereas Spicer *et al*. (2003) give 15 million years for altitudes of 4600m in southern Tibet. In contrast, Xu (1981) provides evidence of a very young uplift after 0.5 million years.

We hypothesise that the ancestor of *T. baileyi* managed to survive such a relatively rapid geological uplift of the plateau by retreating into hot spring areas, and that its evolution in this habitat continued though many periods of climate change. As yet there are only very few data available on the morphological and taxonomic evolution of *T. baileyi*; thus one can only speculate about its phylogenetic history. The hemipenial structure might be interpreted as evidence of a relationship with the genus *Elaphe* (Malnate, 1953). Our further studies will be focussing on more detailed mapping of distribution in this species, and will also include molecular phylogenetic analyses.

Because of its apparently very restricted distribution and unique habitat preferences *T. baileyi* should be considered as a species of particular conservation concern. The populations face numerous threats by the increasing commercial use of the few hot springs and are likely to undergo a substantial decline in the near future. The development of infrastructural facilities around the hot springs does not only reduce the snakes' habitat but also directly diminishes the number of individuals since they are trapped as a source of food ((S. Hofmann, pers. data). Field research to further elucidate their distribution and habitat preferences is urgently required with a view to determining their conservation status and the potential impact of habitat changes.

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