Microhabitat selection of the Chinese Fire-bellied Newt, *Cynops orientalis* (David, 1873), in the lowlands of the central plains of China

Patterns of habitat selection and utilization are a central component of any species ecology and natural history (Wasko & Sasa 2010). In general, amphibians are highly susceptible to desiccation, and low humidity may limit their activity (Moore & Moore 1980). Thus, amphibian species are typically nocturnal, tending to shelter in moist refuges by day and become active only at night to avoid high temperatures and dehydration (Tracy 1976; Zug & Zug 1979; Pough et al. 1983; Cohen & Alford 1996; Spieler & Linsenmair 1998).

Among salamanders, habitat characteristics may directly influence demographic parameters such as reproduction (Kats & Sih 1992; Egea-Serrano et al. 2006; Segev et al. 2011) and survivorship (Kats & Sih 1992; Denoël & Lehmann 2006), as well as behaviors related to movement (Loredo et al. 1996; Jenkins et al. 2006) and distributions (Nickerson et al. 2003). By studying a species in variable habitats, it may be possible to better understand population structure and perhaps infer a species response to different environmental factors.

The Chinese Fire-bellied Newt *Cynops orientalis* (David, 1873), is a small-sized salamander [snout-vent length of adult male: 40.1 ± 1.97 mm, range: 36.0 - 43.5 mm; female: 48.0 ± 3.17 mm, range: 34.9 - 54.2 mm], with bright-orange aposematic coloration on the ventral sides (Xie et al. 2011). This species is a common newt in subtropical forests of south China at elevations between 30 and 1,000 m (Fei 1999). Egg-laying extends from mid-March to early June when water temperature is between 14-20 °C, classifying *C. orientalis* as a prolonged breeder (Wells 1977). Eggs are laid singly, wrapped into plants, with a few eggs laid each day (Huang 2011). Typical clutch size may vary between 50 and 250 eggs per female and year (Fei 1999; Huang 2011). Laboratory bred larvae hatched after an average of 20.2 days at 21.4 °C and preyed on furcilia larvae of *Artemia*, adult *Daphnia*, or cut blackworms. Adult and juvenile salamanders chiefly stay in the water or migrate short distances across the land to arrive at other aquatic habitats (Yu personal observation).

Despite its wide distribution range, surprisingly little is known about microhabitat selection of this species. In the present study, the authors tested whether or not *C. orientalis* actively selects its microhabitat and whether or not habitat was utilized differently by males and females.

The field study was conducted from 19 May to 1 June, 2013, in Daguisi National Forest Park (31°5'N, 113°55'E, elevation 218 m a.s.l.), Hubei Province, in the central plains of China. The study area is subtropical and influenced by monsoons. Its climate is mild and humid, annual average rainfall is 1,100 mm, with most rainfall between June and July. Annual average temperature is 15.6 °C. The reserve covers 2,466.7 ha of secondary highland subtropical rainforest with numerous paddy fields and several small reservoirs. The forest vegetation is dominated by redpine (*Pinus massoniana*), Japanese cedar (*Cryptomeria fortune*), Chinese chestnut (*Castanea mollissima*), *Celtis koraiensis*, *Betula platyphylla*, *Paulownia catalpifolia*, and *Phyllostachys bambusoides*. In the paddy fields, dominant plant species include cress (*Oenanthe javanica*), water pepper (*Polygonum hydropiper*), *Artemisia japonica*, annual fleabane herb (*Erigeron annuus*), love grass (*Eragrostis ferruginea*) and *Urophysa henryi*.

In search of salamanders by day (total amount 40 person-days), time was chiefly spent in paddy fields, at streams, small reservoirs, abandoned ponds, and gutters covered by vegetation, which all constitute habitats where salamanders were captured. At each location where a salamander was spotted, six microhabitat characteristics were recorded: vegetation cover (using a spherical densiometer), vegetation height (using a tape measure to measure at four random points), water depth (using a ruler to measure the deepest depth within the waterbody), temperature (using a mercury thermometer to measure the temperature of the waterbody or soil surface when salamanders were found outside the water), distance from the salamander to both the nearest path and vertical surface structure (e.g.,

Table 1: Correlations among the values of six habitat parameters assessed (correlation coefficients are shown). 1 - vegetation cover, 2 - vegetation height, 3 - water depth, 4 - water/soil temperature, 5 - distance from the salamander to the nearest path, 6 - distance from the salamander to the nearest vertical surface structure.

	1	2	3	4	5	6
1		0.37	-0.40	-0.38	0.11	-0.51
2	-0.37		-0.43	-0.09	0.15	-0.26
3	-0.40	-0.43		0.15	0.01	0.33
4	-0.38	-0.09	0.15		-0.15	0.51
5	0.11	0.15	0.01	-0.15		0.05
6	-0.51	-0.26	0.33	0.51	0.05	

soil ridge, wall). A particular habitat component was considered "unavailable" at a salamander site if it was not present within a radius of 25 m. In addition, comparative microhabitat data from within the study area were collected from 33 randomly selected places devoid of salamanders.

The authors computed all non-trivial correlation coefficients (r < 0.70 in all cases) between the values of the six above habitat parameters assessed (Table 1) and included all microhabitat characteristics in the model. A discriminant function analysis (DFA) was used to determine whether or not salamanders actively selected for certain microhabitat features by comparing 82 sites actually used by salamanders to 33 randomly selected places where salamanders were not found. Discriminant functions were generated using a forward stepwise procedure, with variables entered sequentially to evaluate their contribution toward discrimination between groups. Microhabitat usage of males and females was compared using a logistic regression model (forward stepwise variable selection method). All statistical tests were two-tailed and run with the software package SPSS 13.0 (SPSS Inc. 2004).

In the present study 82 adult salamanders (66 males and 16 females) were captured. Thirteen adult salamanders were found in two ponds close to a main road (0.022 ind./m^2), 69 individuals in seven small water bodies (0.037 ind./m^2) of large, abandoned paddies. Thus, *C. orientalis* demonstrated a positive selection for abandoned paddy and avoidance of human-disturbed areas by both male and female salamanders (Pearson Chi-Square test: χ^2 = 5.38, df = 1, p = 0.02). Thirteen salamanders found in near-main-road ponds (0.022 ind./m^2) would, on the other hand, indicate some preference for near-main-road ponds when compared to 69 salamanders found in the total area occupied by paddy fields (0.008 ind./m^2).

Any analysis of habitat preference depends highly on the definitions of "used" and "available" (JOHNSON 1980; RETTIE & MC-LOUGHLIN 1999; ROSENBERG & MCKELVEY 1999; WASKO & SASA 2010). Structural microhabitat characteristics (Table 2) of randomly selected, unused sites differed significantly from those of sites actually used by salamanders (Wilks' λ = 0.336, χ^2 = 121.53, df = 3, p > 0.001), implying that overall microhabitat usage by *C. orientalis* was nonrandom. The observed microhabitat usage differed significantly from a hypothetical microhabitat usage at randomly available structures in terms of vegetation cover (r = 0.90, $F_{1, 113}$ = 178.67, p > 0.001), vegetation height (r = 0.35, $F_{1, 113}$ = 27.55, p > 0.001) and water depth (r = -0.17, $F_{1, 113}$ = 6.25, p = 0.014).

Significant differences between male and female preferences of certain microhabitat characteristics were not detected by the logistic regression model, although the parameters 'distance from the nearest path (B = 2.60, Wald = 1.33, df = 1, p = 0.25) and temperature (B = -42.31, Wald = 0.88, df = 1, p = 0.35) were included.

In the field, *C. orientalis* was found to be highly sedentary when considering the daily movement pattern, animals often remaining in the same location for one day at a time and moving only briefly and directly between subsequent relocation sites (YU personal observations). Therefore, each relocation point reflects the entirety of an individual's locomotor activity for a period of several hours to one day.

The microhabitat used differed significantly from randomly chosen sites unused by the salamander (Table 2), suggesting active microhabitat selection during the day. The significant preference of dense vegetation cover and tall vegetation during the day suggested that both may be important for

Table 2: Microhabitat description of 82 sites inhabited by the Chinese Fire-bellied Newt, *Cynops orientalis* (DAVID, 1873), compared with 33 randomly selected neighboring sites that were not inhabited by *C. orientalis*. The study was conducted at Daguisi National Forest Park in the lowland central plains of China. The values are presented as mean ± one standard deviation.

Habitat variables	Habitats inhabited by salamanders	Habitats not inhabited by salamanders
Water depth (cm)	6.71 ± 6.18	9.63 ± 4.13
% Vegetation cover	84.06 ± 10.34	46.39 ± 19.73
Vegetation height (cm)	35.22 ± 27.37	9.64 ± 8.83
Distance from the salamander to the nearest path (m)	7.00 ± 7.36	4.70 ± 3.72
Distance from the salamander to the nearest vertical structure (m)	1.84 ± 2.10	6.20 ± 5.96
Water or terrestrial temperature (°C)	25.69 ± 2.21	27.87 ± 2.93

thermoregulation and to avoid predation by, e. g., snakes, which were numerous in the habitat. For example, a *Gloydius brevicaudus* (STEJNEGER, 1907) was seen feeding on a salamander at the study site. However, paddy fields and areas cleared for human usage featured reduced canopy closure, ground vegetation and structural cover. These factors may expose salamanders to increased predation risk (EGAN & PATON 2004; HAMER & MCDONNELL 2008) or increase their likelihood of detection by potential predators (SMOLINSKÝ & GVOŽDÍK 2009).

Commonly, *C. orientalis* was found submerged in the water, maybe due to its relatively weak ability to prevent water evaporation through the skin (LU 1999). As is typical for pond-dwelling salamanders, *C. orientalis* selected habitats with low water depth, to save energy when surfacing for taking breath. During the daytime, the salamanders were almost completely inactive at the bottom of the water.

The above results are consistent with observations made on the salamandrid pond-type newts, *Triturus cristatus* (LAURENTI, 1768) and *Lissotriton vulgaris* (LINNAEUS, 1758) by GRIFFITHS & MYLOTTE (1987) and clearly differ from the microhabitat features described for stream-type salamanders and larvae or terrestrial urodelans such as various species of plethodontid and ambystomatid salamander (MCKENZIE & STORM 1970; MUSHINSKY 1976; KEEN 1982, 1985; LORED et al. 1996).

ACKNOWLEDGMENTS: The authors thank the Daguisi State Forest Farm, Daguisi National Forest Park for permission to conduct research in Guangshui. This work was supported by Joint Funds for Fostering Talents of NSFC and the People's Government of the Henan Province (Grant no. U1204306).

REFERENCES: COHEN, M. P. & ALFORD, R. A. (1996): Factors affecting diurnal shelter use by the Cane Toad, *Bufo marinus*.- Herpetologica, Emporia; 52: 172-181. DENOËL, M. & LEHMANN, A. (2006): Multi-scale effect of landscape processes and habitat quality on newt abundance: implications for conservation.- Conservation Biology, Malden; 130: 495-504. EGAN, R. S. & PATON, P. W. C. (2004): Within-pond parameters affecting oviposition by wood frogs and spotted salamanders.– Wetlands, Dordrecht; 24: 1-13. EGEA-SERRANO, A. & OLIVA-PATERNA, F. J. & TORRALVA, M. (2006): Breeding habitat selection of *Salamandra salamandra* (LINNAEUS, 1758) in the most arid zone of its European distribution range: application to conservation management.- Hydrobiologia, Dordrecht; 560: 363-371. FEI, L. (1999): Atlas of amphibians of China. Zhengzhou (Henan Science and Technology Press), pp. 432. GRIFFITHS, R. A. & MYLOTTE, V. J. (1987): Microhabitat selection and feeding relations of smooth and warty newts. *Triturus vulgaris* and *T. cristatus*, at an upland pond in mid-Wales.- Holarctic Ecology, Malden; 10: 1-7. HAMER, A. J. & MCDONNELL, M. J. (2008): Amphibian ecology and conservation in the urbanizing world: a review.- Conservation Biology, Malden; 141: 2432-2449. HUANG, B. (2011): Study on the breeding biology of artificial beeding *Cynops orientalis*.- Sichuan Journal of Zoology, Chengdu; 30: 581-585. JENKINS, C. L. & MCGARIGAL, K. & TIMM, B. C. (2006): Orientation of movements and habitat selection in a spatially structured population of Marbled Salamanders (*Ambystoma opacum*).- Journal of Herpetology, St Louis; 40: 240-248. JOHNSON, D. H. (1980): The comparison of usage and availability measurements for evaluating resource preference.- Ecology, Washington; 61: 65-71. KATS, L. B. & SIH, A. (1992): Oviposition site selection and avoidance of fish by streamside salamanders (*Ambystoma barbouri*).- Copeia, Washington; 1992: 468-473. KEEN, W. H. (1982): Habitat selection and interspecific competition in two species of plethodontid salamanders.- Ecology, Washington; 63: 94-102. KEEN, W. H. (1985): Habitat selection by two streamside plethodontid salamanders.- Oecologica, New York; 66: 437-442. LOREDO, I. & VAN VUREN, D. & MORRISON, M. L. (1996): Habitat use and migration behavior of the

California tiger salamander.- Journal of Herpetology, St. Louis; 30: 282-285. LU, Y. Y. (1999): Comparison of skin of tailless amphibian.- Journal of Economic Animal, Jilin; 3: 34-37. MCKENZIE, D. S. & STORM, R. M. (1970): Patterns of habitat selection in the clouded salamander, *Aneides ferreus* (COPE).- Herpetologica, Emporia; 26: 450-454. MOORE, R. G. & MOORE, B. A. (1980): Observations on the body temperature and activity in the Red-spotted Toad, *Bufo punctatus*. Copeia, Washington; 1980: 362-363. MUSHINSKY, H. R. (1976): Ontogenetic development of microhabitat preference in salamanders: the influence of early experience.- Copeia, Washington; 4: 755-758. NICKERSON, M. A & KRYSKO, K. L. & OWENS, R. D. (2003): Habitat differences affecting age class distributions of the Hellbender salamander, *Cryptobranchus alleganiensis*.- Southeastern Naturalist, Steuben; 2: 619-629. POUGH, F. H. & TAIGEN, T. L. & STEWART, M. M. & BRUSSARD, P. F. (1983): Behavioral modification of evaporative water loss by a Puerto Rican frog.- Ecology, Washington; 64: 244-252. RETTIE, W. J. & MCLOUGHLIN, P. D. (1999): Overcoming radiotelemetry bias in habitat-selection studies.- Canadian Journal of Zoology, Ottawa; 77: 1175-1184. ROSENBERG, D. K. & MCKELVEY, K. S. (1999): Estimation of habitat selection for central-place foraging animals.- Journal of Wildlife Management, Bethesda; 63: 1028-1038. SEGEV, O. & MANGEL, M. & WOLF, N. & SADEH, A. & KERSHENBAUM, A. & BLAUSTEIN, L. (2011): Spatiotemporal reproductive strategies in the fire salamander: a model and empirical test.- Behavioral Ecology, Oxford; 22: 670-678. SMOLINSKÝ, R. & GVOŽDÍK, L. (2009): The ontogenetic shift in thermoregulatory behaviour of newt larvae: testing the 'enemy-free temperatures' hypothesis.- Journal of Zoology, London; 279: 180-186. SPIELER, M. & LINSENMAIR, K. E. (1998): Migration patterns and diurnal use of shelter in a ranid frog of a West African savannah: A telemetric study.- Amphibia-Reptilia, Leiden; 19: 43-64. TRACY, C. R. A. (1976): Model of the dynamic exchanges of water and energy between a terrestrial amphibian and its environment.- Ecological Monographs, Washington; 46: 293-326. WASKO, D. K. & SASA, M. (2010): Habitat selection of the terciopelo (Serpentes: Viperidae: *Bothrops asper*) in a lowland rainforest in Costa Rica.- Herpetologica, Emporia; 66: 148-158. WELLS, K. D. (1977): The social behaviour of anuran amphibians.- Animal Behaviour, London; 25: 666-693. XIE, Z. H. & WANG, X. T. & CHEN, L. Y. & LI, X. & TANG, C. & LIU, F. & YANG, J. Y. (2011): Analysis of sexual size dimorphism of *Cynops orientalis*.- Sichuan Journal of Zoology, Chengdu; 30: 772-776. ZUG, G. R. & ZUG, P. B. (1979): The Marine Toad *Bufo marinus*: A natural history résumé of native populations.- Smithsonian Contributions to Zoology, Washington; 284: 1-54.

KEYWORDS: Amphibia: Caudata: Salamandridae; *Cynops orientalis*, ecology, habitat selection, behavior, Daguisi National Forest Park, Hubei Province, China

SUBMITTED: October 10, 2013

AUTHORS: Tong Lei YU (Corresponding author; < yutonglei_00000@163.com >), Jian Bin CHEN - Department of Biology, College of Life Science, Xinyang Normal University, SD 464000, China.