*

(　　　　　　　　　　,　　　310036)

8　　　　　　　　　　　　　　(*Eumeces chinensis*)　　,

　　　　　　　　　　　　　,

　　　　　　　　　　　　;　　　　　　　　　　　　　　　,　24　32　　　　　　,
　　　　　　32　　　　　　　　　　　　　　　,　　　　　　　　　　　　　　　　　,
　32　　　　　　　　　　　　　　,　　　　　(snout-vent length , SVL)

　　,

　　　　　　,　　　　　　　　　　　24　　　　　　　　　,
　　　　　　　　, 30　　　　　　　　　, 32

26　30

:
　　　　　　　　　　　,

(Deeming *et al.* , 1991) ,　　　　　　　　　　　　　　　　　　　　　　(Lutz
et al. , 1984 ; Packard *et al.* , 1984 , 1986 , 1988 ;
　(Vinegar , 1974)　　　　　　　　　　Gutzke *et al.* , 1987 ; Packard , 1991) ,

　　　　　　,　　　　　　　　　　　,　　　　　　　　　　　(　　　　, 1998 ; Tracy ,
　　　　　　　　　　　,　　　　　1980 ; Hotaling *et al.* , 1985 ; Plummer *et al.* ,
　　　　　　　　　　　　　　　　1988 ; Ratterman *et al.* , 1989 ; Ji *et al.* , 1999a ;
　　　　　(rigid-shelled egg)　　　1999b)
　(pliable-shelled egg) ,

　　　　　　　　　　　　　,　　　　　　　　　　　　　　　　　　　　　　　　　,　　　　　　,
　　　　　　　　　　　　　　　　,
　　　　,　　　　　　　　　(　　　, 1966 ; De Fraipont *et al.* ,
　　　(　　　　　　, 1998 ; Vleck , 1991 ; Overall , 1996 ; Ji *et al.* , 1996)
1994 ; Ji , 1992 ; Ji *et al.* , 1996 , 1997a , 1997b ,　　　　　　　　　　(1)
1999a ; Braña *et al.* , 2000)　　　　,　　　　　　　　　　; (2)　　　　　; (3)　　　　(
　　　　　　　　　　　　　　　　　　　　　　　　　　)

1

1998 5

,

(900 mm × 650 mm ×
500 mm) , 8

,

(larvae of *Tenebrio molitor*) [

(Nekton-Rep)
] 300 W

, 24

, (
, 1995) 5 31 6 28

1 hr
120 mm ( )
1/3 ,

,

LRH-250A ,

2 (
) ×4 ( ) 0 kPa
- 220 kPa , (vermiculite) = 1 3
1 1 ; 24 26 30
32 , ;
5 ,
1 hr ,
30 ,
(,
1995) Panasonic NV-DS77

2 000 mm ×100 mm ×150 mm
, ,
250 mm
( ) ,
,

,
, 65
(non-polar lipids)
55 5.5 hr ,
GR-3500
( )
700 12 hr
, Kol-

mogorov-Smirnov Bartlett （STATISTICA
）
ln ( )
G (one-way) (two-way)
(ANOVA)
(ANCOVA) Post-hoc (Tukey's
)

± ,
, =
0.05

2

2.1

(all $P < 0.01$)

(two-way ANCOV-
A , all $P < 0.05$) ;

(one-way
ANCOVA , all $P < 0.0001$) (1A D)
ANCOVA ($F_{3,420} = 90.37$, $P <
0.0001$) ($F_{1,420} = 374.85$, $P < 0.0001$)
(all $P <
0.05$) : 26 / - 220 kPa 30 / (220 kPa
(Tukey's test , $P > 0.05$) ,
24 /0 kPa 30 /0 kPa
(Tukey's test , $P > 0.05$) ,
(Tukey's test ,
all $P < 0.0001$)

2.2

ANOVA (ln
) ($F_{3,436} = 9209.69$, $P < 0.0001$) , ($F_{1,436}
= 1.47$, $P = 0.225$)
($F_{3,436} = 1.59$, $P = 0.191$)
24 26 ,
10.0 d ; 26 30 , 11.1 d ; 30
32 , 1.4 d (1)

,
(G-test , $P > 0.05$)

2.3

(ln) ,
(2)

卵质量 （Egg mass(mg)）

孵化天数 (Days of incubation)

1
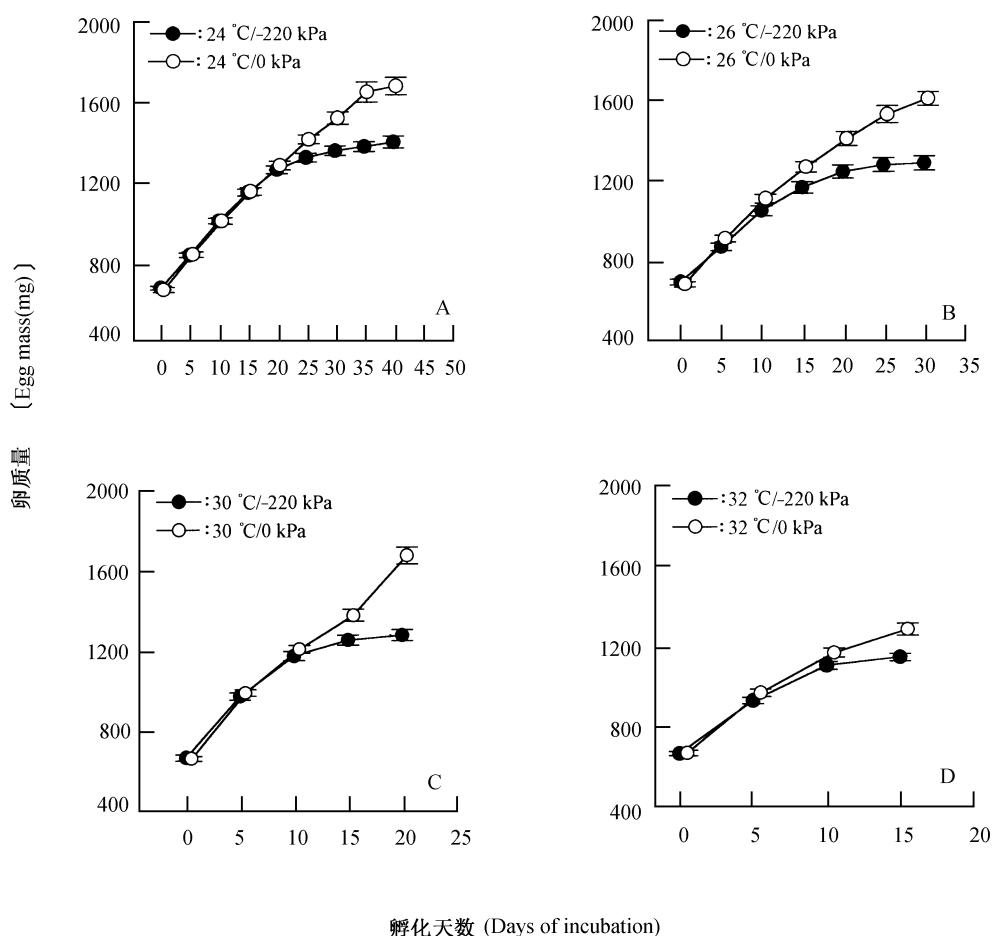
Fig. 1   Temporal changes in mass of Eumeces chinensis **eggs incubated in
different thermal and hydric environments**

±   ,   (Data are expressed as mean ± S E. Sample sizes are indicated in the figures)

1

**Table 1   Effects of thermal and hydric environments
on duration of incubation and hatching success
in** Eumeces chinensis

/ (/ kPa) Temperature/ Moisture	Incubated eggs	(d) Duration of incubation	(%) Hatching success
24/ - 220	78	41. 7 ± 0. 2 (35. 5 45. 8)	87. 2 (68/ 78)
24/ 0	69	41. 4 ± 0. 2 (35. 9 45. 0)	76. 9 (53/ 69)
26/ - 220	51	32. 0 ± 0. 2 (27. 1 35. 8)	88. 9 (45/ 51)
26/ 0	75	31. 4 ± 0. 2 (29. 0 34. 9)	88. 0 (66/ 75)
30/ - 220	56	20. 5 ± 0. 1 (17. 8 22. 7)	92. 9 (52/ 56)
30/ 0	51	20. 5 ± 0. 1 (18. 0 22. 5)	83. 3 (47/ 51)
32/ - 220	72	19. 0 ± 0. 1 (18. 0 21. 6)	80. 6 (58/ 72)
32/ 0	62	19. 2 ± 0. 1 (16. 3 22. 1)	88. 7 (55/ 62)

; 32
24   26   30   ,
SVL   ; 30
, 26   32
24   (2)

,
ANCOVA

,   ANOVA

(2)
,
; 32
24   26   30   ,
(2)

, **2.4**

; 24 32 ,

(4)

, (2) , 24

AN- , 24 32 ,

COVA 30 26 30 (4)

, 32 , 24

(3) (4)

(3)

2

Table 2　Body mass, snout-vent length, tail length of Eumeces chinensis **hatchlings from the eggs incubated in different thermal and hydric environments**

/ (/ kPa) Temperature/ Moisture	(n)	(mg) Body mass		(mm) Snout-vent length	(mm) Tail length	(mg) Carcass dry mass	(mg) Yolk sac dry mass	(mg) Fat body dry mass
		(Wet mass)	(Dry mass)					
24/ - 220	68	680.6 ± 8.8 (541.3 938.4)	147.4 ± 2.5 (91.9 200.8)	29.7 ± 0.3 (23.0 32.3)	35.8 ± 0.3 (25.8 42.2)	131.3 ± 2.1 (80.4 178.1)	15.7 ± 1.9 (3.6 43.0)	0.36 ± 0.04 (0.1 1.6)
24/0	53	676.1 ± 10.0 (562.0 887.7)	143.7 ± 2.6 (113.2 197.2)	30.0 ± 0.2 (26.3 32.4)	35.7 ± 0.4 (29.2 42.1)	128.3 ± 2.3 (88.4 168.3)	15.1 ± 1.2 (1.2 48.3)	0.29 ± 0.03 (0.1 1.1)
26/ - 220	45	683.4 ± 13.2 (536.7 936.3)	153.6 ± 3.8 (109.6 217.0)	29.8 ± 0.3 (24.7 33.3)	35.8 ± 0.5 (27.6 41.3)	130.2 ± 3.1 (82.3 179.5)	23.0 ± 2.6 (2.9 90.4)	0.37 ± 0.05 (0.1 1.1)
26/0	66	689.8 ± 11.5 (486.8 943.2)	148.6 ± 2.8 (105.7 204.5)	30.2 ± 0.2 (25.0 33.0)	37.1 ± 0.3 (30.0 43.6)	130.8 ± 2.2 (90.7 183.1)	17.4 ± 1.2 (4.1 57.4)	0.36 ± 0.03 (0.1 1.1
30/ - 220	52	670.9 ± 13.3 (479.1 918.2)	148.6 ± 3.3 (89.5 214.6)	29.8 ± 0.2 (25.4 32.8)	37.2 ± 0.5 (26.6 45.3)	127.5 ± 2.7 (69.2 170.7)	20.8 ± 1.9 (2.7 75.0)	0.34 ± 0.04 (0.1 1.3)
30/0	47	673.9 ± 9.9 (576.3 859.9)	147.9 ± 2.9 (92.2 193.8)	30.3 ± 0.2 (25.1 33.0)	38.2 ± 0.4 (31.9 49.6)	129.1 ± 2.4 (80.8 166.7)	18.4 ± 1.3 (7.0 41.4)	0.34 ± 0.04 (0.1 1.3)
32/ - 220	58	646.8 ± 9.6 (498.7 837.9)	147.5 ± 2.5 (109.7 201.6)	29.2 ± 0.2 (25.5 31.7)	35.6 ± 0.4 (26.7 41.5)	118.1 ± 2.2 (70.0 150.5)	29.1 ± 1.9 (5.8 64.4)	0.34 ± 0.04 (0.1 1.4)
32/0	55	656.0 ± 10.8 (507.8 851.4)	142.9 ± 3.0 (63.9 194.0)	29.4 ± 0.2 (24.6 31.7)	36.2 ± 0.4 (28.6 41.4)	117.6 ± 2.4 (61.1 158.5)	25.1 ± 1.6 (2.7 62.5)	0.28 ± 0.03 (0.1 0.9)
(Moisture) $F_{1,435}$		5.05* WS > DS	2.58 ns	9.62** WS > DS	8.25** WS > DS	0.23 ns	5.07* WS < DS	0.76 ns
(Temperature) $F_{3,435}$		7.34*** 24[a], 26[a], 30[a], 32[b]	1.78 ns	6.50*** 24[a], 26[a], 30[a], 32[b]	12.43*** 24[c], 26[b], 30[a], 32[b]	14.57*** 24[a], 26[a], 30[a], 32[b]	26.01*** 24[c], 26b[c], 30[b], 32[a]	1.43 ns
(Interaction) $F_{3,435}$		0.35 ns	0.34 ns	0.23 ns	1.31 ns	0.51 ns	0.23 ns	0.39 ns

(Notes): ANOVA ( ) ANCOVA ( ) F [F values correspond to single effects and factor interactions in two-way ANOVA (for fat body dry mass) and two-way ANCOVAs (with initial egg mass as the covariate)]

(Tukey's test, = 0.05), a > b > c [Means with different superscripts differ significantly (Tukey's test, = 0.05), a > b > c]

WS: (0 kPa) [Wetter substrate (0 kPa)]　DS: (- 220 kPa) [Drier substrate (- 220 kPa)]

ns: P > 0.05　* P < 0.05　** P < 0.01　*** P < 0.001

3

Table 3   Body shape and head size of Eumeces chinensis **hatchlings from the eggs incubated in different thermal and hydric environments**

Temperature/ Moisture (/ kPa)	Sample size (n)	Body mass (mg)	Tail length (mm)	Head length (mm)	Head width (mm)
24/ - 220	68	690. 1 ± 7. 4	36. 2 ± 0. 2	7. 5 ± 0. 03	5. 2 ± 0. 03
24/ 0	53	676. 1 ± 9. 3	35. 7 ± 0. 3	7. 4 ± 0. 03	5. 2 ± 0. 03
26/ - 220	45	689. 8 ± 8. 9	36. 1 ± 0. 3	7. 5 ± 0. 03	5. 1 ± 0. 03
26/ 0	66	683. 9 ± 7. 5	36. 8 ± 0. 2	7. 5 ± 0. 02	5. 1 ± 0. 02
30/ - 220	52	677. 3 ± 8. 8	37. 5 ± 0. 3	7. 4 ± 0. 02	5. 1 ± 0. 03
30/ 0	47	663. 3 ± 9. 2	37. 7 ± 0. 4	7. 4 ± 0. 03	5. 0 ± 0. 03
32/ - 220	58	675. 3 ± 6. 9	36. 9 ± 0. 2	7. 4 ± 0. 02	5. 0 ± 0. 02
32/ 0	55	676. 9 ± 8. 0	37. 1 ± 0. 3	7. 4 ± 0. 02	4. 9 ± 0. 03
(Moisture)	$F_{1,435}$	1. 89 ns	0. 52 ns	0. 50 ns	0. 55 ns
(Temperature)	$F_{3,435}$	1. 52 ns	15. 40 *** 24[b], 26[b], 30[a], 32[b]	4. 38 ** 24[a], 26[a], 30[ab], 32[b]	22. 16 *** 24[a], 26[b], 30[b], 32[c]
(Interaction)	$F_{3,435}$	0. 42 ns	1. 94 ns	0. 17 ns	2. 55 ns

(Notes)：   ANCOVA (SVL   ) F ±   [F values correspond to single effects and factor interactions in two-way ANCOVAs (with hatchling SVL as the covariate) Data are expressed as adjusted means ± SE]

（Tukey's test，   = 0. 05），a > b > c [Means with different superscripts differ significantly (Tukey's test，   = 0. 05)，a > b > c]

$ns:$ $P > 0. 05$ ** $P < 0. 01$ *** $P < 0. 001$

4

Table   Effects of incubation temperature on energy contents, lipid mass and ash mass of Eumeces chinensis **hatchlings and dry mass and ash mass of hatched egg shells**

Temp. ( )	Sample size (n)	Hatchling				Eggshell	
		(Dry mass) (mg)	(Energy) (KJ)	(Non-polar lipids) (mg)	(Ash mass) (mg)	(Dry mass) (mg)	(Ash mass) (mg)
24	121	146. 3 ± 1. 2	3. 38 ± 0. 03	34. 8 ± 0. 5	15. 5 ± 0. 1	8. 1 ± 0. 1	0. 82 ± 0. 01
26	111	148. 0 ± 1. 4	3. 43 ± 0. 03	36. 1 ± 0. 6	15. 8 ± 0. 1	7. 7 ± 0. 1	0. 79 ± 0. 01
30	99	150. 4 ± 1. 4	3. 55 ± 0. 04	37. 5 ± 0. 6	16. 2 ± 0. 1	7. 2 ± 0. 1	0. 73 ± 0. 01
32	112	147. 9 ± 1. 4	3. 53 ± 0. 04	32. 1 ± 0. 9	16. 2 ± 0. 1	7. 2 ± 0. 1	0. 73 ± 0. 01
$F_{3,438}$		1. 35 ns	5. 30 ** 24[b], 26[ab], 30[a], 32[a]	16. 10 *** 24[b], 26[a], 30[a], 32[b]	3. 96 ** 24[b], 26[ab], 30[a], 32[a]	19. 01 *** 24[a], 26[a], 30[b], 32[b]	19. 82 *** 24[a], 26[ab], 30[b], 32[b]

(Notes)：   ±   ，   (680 mg)   (Data are expressed as adjusted means ± SE, with initial egg mass (set at 680 mg) as the covariate)，   （Tukey's test，   = 0. 05，a > b) [Adjusted means with different superscripts differ significantly (Tukey's test，   = 0. 05)，a > b]

F (ANCOVA)   (F values of ANCOVAs are indicated. Symbols immediately after F values represent significant levels)

$ns:$ $P > 0. 05$ ** $P < 0. 01$ *** $P < 0. 001$

2. 5 　

SVL （ $r = 0.21$, $F_{1,342} = 16.27$, $P < 0.0001$ ） 　　　　　　（ $r = 0.24$, $F_{1,342} = 20.03$, $P < 0.0001$ ） 　　　　　　　　　 , 　　　　　　 [　ln（ 　 ） 　 Ln （ 　 　 ） 　　　　　　　　] 　 （ $r = 0.06$, $F_{1,342} = 1.49$, $P = 0.222$ ） 　　　　　　　　　　　　 （ANOVA , $F_{3,340} = 12.65$, $P < 0.0001$ ）, 32 　　　　　　　　　　　 24 　 30 　　　　　 ; 　ANCOVA 　 （ 　 ） 　　　　　　　　 , 　　　　　　 （ANCO- VA , $F_{3,339} = 10.28$, $P < 0.0001$ ） （ 　 5 ）

5 　

（ 　 30 　 ）

Table 5　Effects of incubation temperature on sprint speed of *Eumeces chinensis* **hatchlings**

（the body temperature of 30 　 ）

（ 　 ）Temperature	Sample size （ n ）	（m/s）Observed values		（m/s）Adjusted values	
		(Mean)	SE	(Mean)	(SE)
24	95	0.49[a]	0.02	0.49[a]	0.02
26	84	0.53[a]	0.02	0.52[a]	0.02
30	77	0.47[a]	0.02	0.46[a]	0.02
32	88	0.38[b]	0.02	0.39[b]	0.02

（Notes）: 　　　　　　　　　　　 （Means with different superscripts differ significantly）

3 　

　　　　　　 , 　　　　　　　　　　　　　 （ 　　 ） 　 （ 　　 ） 　 （ 　　 ） 　 （Ackerman *et al.* , 1985 ; Packard *et al.* , 1988 ; Vleck , 1991） 　 , 　

　　　　 : （1） 　　　　 ; （2） 　 , 　 ; （3）

　 , 　 , 　

　 , 　 　

　　　 Eumeces 　　 *Eumeces* 　　　　　　 （ 　 , 1966 ; De Fraipont *et al.* , 1996） , 　

　 , 　 （ 　 , 1995 ; 　 , 2000 ; Ji *et al.* , 1996） 　 ,

　 （Rose , 1981 ; Andrews *et al.* , 1994） , 　

　 ,

　 ,

　 , 　 （Tracy *et al.* , 1985 ; Gutzke *et al.* , 1987 ; Packard *et al.* , 1988 ; Phillips *et al.* , 1990 ; Packard *et al.* , 1993 ; Phillips *et al.* , 1994 ; Janzen *et al.* , 1995） , 　 （ 　 , 1998 ; 　 , 2001 ; Packard *et al.* , 1987 ; Plummer *et al.* , 1988 ; Thompson , 1990 ; Overall , 1994 ; Castilla *et al.* , 1996 ; Ji *et al.* , 1999a ; Braña *et al.* , 2000） 　 : （1）

　 ; （2）

　 , 　 , 　 （Deeming *et al.* , 1991 ; Van Damme *et al.* , 1992 ; Ji *et al.* , 1999a） 　 ,

: (1)

                ; (2)   ,

(3)   ,

     (32   )   30   ,

                    ,   24   30   ,   SVL

1988 ; Phillips *et al .* , 1990 , 1994 ; Van Damme *et*   32

al . , 1999a)

          (+   )   (   )   ,

          , 32   (Garland , 1985 ; Huey   *et   al .* , 1990 ;

                                   (Bauwens *et al .* , 1995 ; Braña *et al .* , 2000)

2)   24   ,   , 24   30

          (, 1999c ; Ji *et al .* , 1996 ;   , ANCOVA   (   )

1997a ; 1997b ; 1999a ; 2000) , 24

     ,   ,   (

               (4)   , 24   ,   )

     (1) ,   (4)

               (24   30   )

     ,   26   30

(Gutzke *et al .* , 1987 ; Beuchat , 1988 ; Packard *et*   32

al . , 1988 ; Phillips   *et   al .* , 1990 , 1994 ; Van   24

Damme *et al .* , 1992 ; Ji *et al .* , 1999a)   ,   ,

          (32   )   (,   , 24

3)   32

     ,   ,

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(Abstract)

EFFECTS OF THERMAL AND HYDRIC ENVIRONMENTS ON INCUBATING EGGS , HATCHING SUCCESS , AND HATCHLING TRAITS IN THE CHINESE SKINK (EUMECES CHINENSIS)

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Effects of thermal and hydric environments on incubating eggs , embryonic use of energy and nutrients , and hatchling traits were studied in the Chinese skink (*Eumeces chinensis*) from a population in Lishui , Zhejiang , eastern China. The eggs were incubated at temperatures of 24 , 26 , 30 , and 32   on substrates with water potentials of 0 and - 220 kPa using a 4 × 2 factorial design. All viable eggs increased in mass over the course of incubation due to absorption of water , and mass gain during incubation was dependent on initial egg mass , temperature , and substrate water potential. Variation in the wet mass of hatchlings among treatments stemmed mainly from variation in water content. Temperature profoundly affected duration of incubation , water uptake by eggs during the course of incubation , embryonic use of energy and nutrients , embryonic mobilization of inorganic material from the shell , and almost all hatchling traits examined. However , incubation temperature did not affect hatching success within the range from 24   to 32 . Hatchlings from eggs incubated at 32   were less developed , as indicated by smaller carcasses and more unutilized yolks , and hence were smaller than their siblings from lower incubation temperatures. Moreover , hatchlings from eggs incubated at 32   did not perform as well as their siblings from the temperatures lower than 32   in the racetrack , even when the hatchling size (snout-vent length) was kept constant. This indicates that high incubation temperatures have an impaired effect on locomotor performance of *E*. *chinensis* hatchlings. Eggs incubated in wetter substrates produced larger hatchlings that contained smaller residual yolks than did eggs incubated in drier substrates. At the time of hatching , shells form eggs incubated at 24   were heavier in dry mass and contained more ash than those from eggs incubated at

lower temperatures , suggesting that less inorganic material be withdrawn from the shell by embryos developing at the temperature. Incubation temperature subtly affected body shape and head size of *E. chinensis* hatchlings: hatchlings from eggs incubated at 30 had the longest tails , and hatchlings from eggs incubated at 32 had the smallest heads. On the contrary , substrate water potential was not an important source of variation for body shape and head size of hatchlings. The effects of temperature on hatchling traits were independent of the effects of water potential. Variation in size and mass induced by incubation thermal and hydric environments would be important to post‑hatching survival and fitness of hatchlings. Although temperature did not significantly influence hatching success within the range of 24 to 32 , 26 and 30 were more suitable for incubating *E. chinensis* eggs , as eggs incubated at temperatures within this range produced larger and well‑performed hatchlings at a lower energy expenditure.

Key words Chinese skink（*Eumeces chinensis*）, Egg , Incubation , Hatchling traits , Locomotor performance