

Lithobius (Ezembius) ternidentatus sp. n. (Lithobiomorpha, Lithobiidae), a new species from China

Sujian Pei¹, Haipeng Liu¹, Yanmin Lu¹, Xiaojie Hou¹, Huiqin Ma¹

¹ Institute of Myriapodology, School of Life Sciences, Hengshui University, Hengshui, Hebei 053000, China

Corresponding author: Huiqin Ma (mhq008@yahoo.com)

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Abstract

Lithobius (Ezembius) ternidentatus sp. n. (Lithobiomorpha, Lithobiidae), recently discovered from Wuyuezhai Mountain, Lingshou County, Shijiazhuang City, Hebei Province, China, is described. Morphologically it resembles *L. (E.) multispinipes* Pei, Lu, Liu, Hou, Ma & Zapparoli, 2016, but can be easily distinguished from the latter by having a different sized Tömösváry's organ, different numbers of ocelli, obvious differences in ventral plectrotaxy of legs 14, and tarsal articulation ill-defined on legs 1–13, well-defined on legs 14–15. The main morphological characters of the known Chinese species of the subgenus *Ezembius* Chamberlin, 1919 based on adult specimens is presented.

Keywords

Centipede, Chilopoda, China, Hebei Province, myriapods

Introduction

Ezembius was originally proposed as a subgenus of *Lithobius* Leach, 1814 in the family Lithobiidae by Chamberlin (1919); it accommodates a group of 60 species/subspecies mostly known from Asia, with little extension into north-western North America. Known species colonize a wide range of habitats, from the Arctic and Subarctic to tropical and sub-tropical forests, to steppe and overgrazed stony areas of central Asia, to Himalayan montane forests, from the sea shore up to 5500 m (Himalayas) (Zapparoli and Edgecombe 2011, Qiao et al. 2018). Although the subgenus was formally proposed

as new and described in 1923 (Chamberlin 1923), according to Jeekel (2005) its name had been already validated in 1919 (Chamberlin 1919). *Ezembius* is characterized by antennae with ca 20 articles; ocelli 1+4–1+20; forcipular coxosternal teeth usually 2+2; porodonts generally setiform, sometimes stout. Tergites are generally without posterior triangular projections; tarsal articulation of legs 1–13 is distinct. Female gonopods are with uni-, bi or tridentate claws, and 2+2–3+3 (rarely 4+4) spurs (Zapparoli and Edgecombe 2011).

The myriapod fauna of China is still poorly known and very little attention has been paid to the study of Lithobiomorpha, with only 82 species/subspecies hitherto known from the country. Altogether, 21 species of *Ezembius* have been recorded from China, but none of them have been reported from Hebei Province (Pei et al. 2018, Qiao et al. 2018). Here a new species, recently found in the Hebei Province, China, is described and illustrated. Tables of the main morphological characters of Chinese *Ezembius* species are presented.

Materials and methods

All specimens were hand-collected under leaf litter or stones. The material was examined with the aid of a Motic-C microscope (Xiamen, China). The colour description is based on specimens preserved in 75% ethanol, and the body length is measured from the anterior margin of the cephalic plate to the posterior margin of the postpedal tergite. Type specimens are preserved in 75% ethanol and deposited in the School of Life Sciences, Hengshui University, Hengshui, China (HUSLS). The terminology of the external anatomy follows Bonato et al. (2010).

The following abbreviations are used in the text and the tables: **a**, anterior; **C**, coxa; **DaC spine**, anterior dorsal spine of coxa; **F**, femur; **m**, median; **p**, posterior; **P**, prefemur; **S**, **SS**, sternite, sternites; **T**, **TT**, tergite, tergites; **Ti**, tibia; **To**, Tömösváry's organ; **Tr**, trochanter.

Taxonomy

Lithobiomorpha Pocock, 1895

Lithobiidae Newport, 1844

***Lithobius* Leach, 1814**

***Lithobius* (*Ezembius*) Chamberlin, 1919**

***Lithobius* (*Ezembius*) *ternidentatus* sp. n.**

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Fig. 1A–E, Tables 1, 2

Diagnosis. Body length 7.1–8.5 mm, antennae commonly composed of 24 articles, but also 22+24 or 24+25, 5–6 ocelli on each side of head, arranged in two irregular

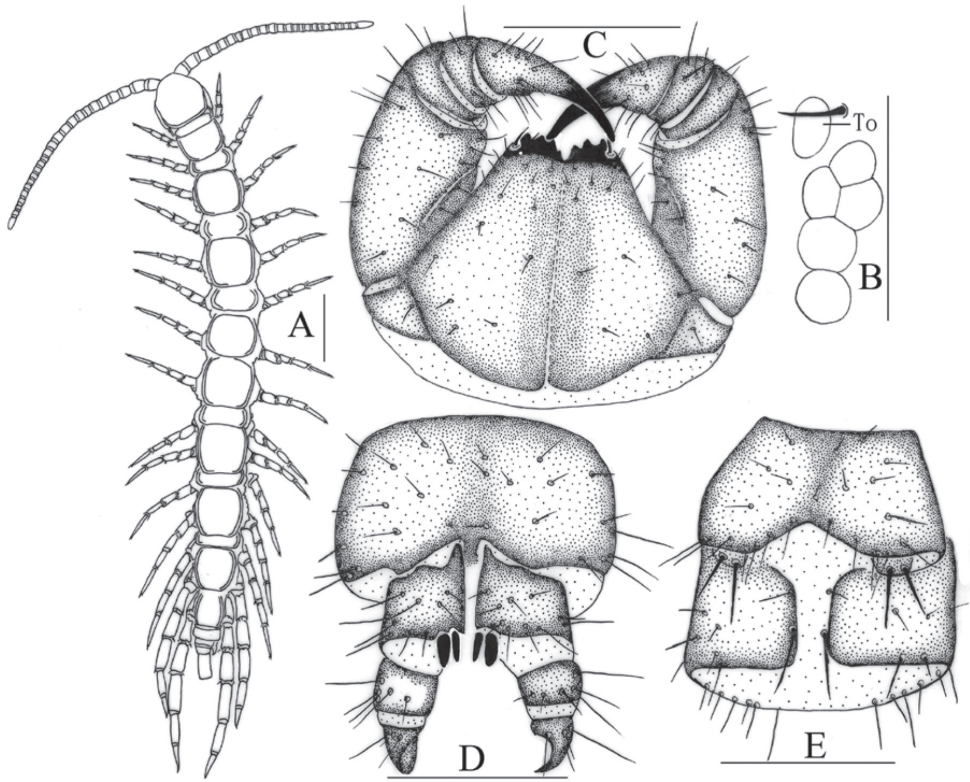


Figure 1. *Lithobius (Ezembius) ternidentatus* sp. n., holotype female and paratype male: **A** male habitus, dorsal view **B** male ocelli and Tömösváry's organ (To), lateral view **C** female forcipular coxosternite, ventral view **D** female posterior segments and gonopods, ventral view **E** male: posterior segments and gonopods, ventral view. Scale bars: 2 mm (**A**); 200 µm (**B**); 250 µm (**C–E**).

rows, posterior two ocelli comparatively large; Tömösváry's organ larger than the adjacent ocelli; commonly 3+3, but also 3+2 or 2+2 prosternal teeth, porodonts moderately slender, posterolateral to the lateral-most tooth, posterior angles of all tergites without triangular projections; coxal pore formula 3-4-4-3, oval to round, arranged in one row; female gonopods with 2+2 moderately small coniform spurs, apical claw simple; male gonopods short and small, with 1–3 long setae on the terminal segment.

Material examined. Holotype: ♀ (Fig. 1), China, Hebei Province, Wuyuezhai Mountain, Lingshou County, Shijiazhuang City, 38°43'15.02"N, 114°08'32.62"E, 480 m, under litter of the forest floor in a mixed coniferous broad-leaved forest, 28 Sept 2014, leg. S. Pei, H. Ma. **Paratypes:** 33♀♀, 38♂♂, same data as holotype. **Other material:** 9♀♀, 6♂♂, China, Hebei Province, Shanyanggou, Longquanguan Town, Fuping County, Baoding City, 38°50'13.57"N, 114°03'26.93"E, 941 m, 7 Sept 2014, leg. S. Pei, H. Ma. Type specimens and other material are deposited in the HUSLS.

Description. *Body* length: 7.1–8.5 mm, cephalic plate 0.75–0.97 mm long, 0.60–0.75 mm wide.

Colour: antennal articles and whole body pale yellow-brown, tergites darker, pleural region and sternites pale yellow with greyish hue; basal and proximal parts of forcipules, forcipular coxosternite, and SS XIV and XV darker.

Antennae: 22–25 articles, commonly 24 articles (Fig. 1A), 2 specimens 22+24, 3 specimens 24+25 articles; antennae articles length is approximately equal to width except basal articles II–V slightly longer than wide, distal-most article 2.7–3.1 times as long as wide; abundant setae on the antennal surface, less so on the basal articles, gradual increase in density of setae to about the fourth article, then more or less constant.

Cephalic plate smooth, convex, slightly wider than long; tiny setae emerging from pores scattered very sparsely over the whole surface; frontal marginal ridge with shallow anterior median furrow; short to long setae scattered along the marginal ridge of the cephalic plate; lateral marginal ridge discontinuous, posterior margin continuous, straight, wider than lateral marginal ridge (Fig. 1A).

Five or six oval to rounded ocelli on each side (Fig. 1B), most of them rounded, domed, translucent, usually darkly pigmented, situated in two irregular rows; the posterior two ocelli comparatively large; others subequal in size.

Tömösváry's organ situated at anterolateral margin of the cephalic plate, about same size as the largest two ocelli and lying well apart from them (Fig. 1B).

Coxosternite subtrapezoidal (Fig. 1C), anterior margin narrow, lateral margins slightly longer than medial margins; median diastema moderately deep, narrow V-shaped; anterior margin with 3+3 acute triangular teeth, very few 2+2 (8% of studied individuals) or 2+3 (3% of studied individuals); porodonts slender, lying posterolateral to and separated from the lateral-most tooth (Fig. 1); scattered long setae on the ventral side of coxosternite, longer setae near the dental margin.

All tergites smooth, without wrinkles, dorsum slightly convex; tiny setae emerging from pores scattered sparsely over the entire surface, near the margin with few long setae; T I narrower posterolaterally than anterolaterally, generally trapezoidal, narrower than the cephalic plate and T III, obvious shorter than T III, the cephalic plate slightly wider than T III. Lateral marginal ridges of all tergites continuous. Posterior margin of TT I, III, V, and VII slightly concave, posterior marginal ridges continuous. Posterior margins of TT VIII, IX, XI, XIII, and XV concave, posterior marginal ridges discontinuous. Posterior angles of tergites generally rounded, without triangular projections. Miniscule setae scattered sparsely over the surface, 3–5 slightly thick and long setae on anterior and posterior angles of each tergite.

Posterior side of sternites narrower than anterior side, generally trapezoidal, smooth; setae emerging from sparsely scattered pores on the surface and lateral margin, few long setae on the surface of the anterior part of each sternite, 1–2 comparatively long setae scattered sparsely on the surface respective both of the middle part and posterior part of each sternite.

Legs robust, tarsal articulation ill-defined on legs 1–13, well-defined on legs 14–15; all legs with fairly long curved claws; legs 1–13 with anterior and posterior accessory spurs; anterior accessory spurs moderately long and slender, forming a moderately

Table 1. Leg plectrotaxy of *Lithobius (Ezembius) ternidentatus* sp. n.

Legs	Ventral					Dorsal			
	C	Tr	P	F	Ti	C	Tr	P	Ti
1–9			mp	amp	am			ap	ap
10			mp	amp	am	a		ap	ap
11			mp	amp	am	a		amp	ap
12			(a)mp	amp	am	a		amp	p
13		m	amp	amp	am	a		amp	p
14		m	amp	am	am	a		amp	p
15		m	amp	am	a	a		amp	p

N.B. Letters in brackets indicate variable spines.

small angle with the claw, posterior accessory spurs slightly more robust, forming a comparatively large angle with the claw, legs 14 and 15 only with small posterior accessory spurs; long setae sparsely scattered over the surface of prefemur, femur and tibia of all legs, more setae on the tarsal surface; setae on dorsal surface of tarsus slightly shorter than the ventral, one row of thicker setae regularly arranged on the medial ventral side of tibia of legs 1–13, with setae significantly reduced in legs 14 and 15, no thicker setae regularly arranged in one row on the medial ventral side of tibia; legs 14 and 15 moderately thicker and longer than the anterior pairs in the female; leg plectrotaxy as in Table 1.

Coxal pores 3-3(4)-4(5)-3, commonly 3-4-4-3, round to slightly oval, in a row; coxal pore field set in a relatively shallow groove, the coxal pore-field fringe with prominence; prominence with short to moderately long setae sparsely scattered over the surface.

Female S 15 anterior margin broader than posterior, generally trapezoidal, postero-medially straight, colour yellow-brown; short to long sparse setae evenly scattered on surface; surface of the lateral sternal margin of genital segment well chitinized, posterior margin of genital sternite deeply concave between condyles of gonopods, except for a small, median tongue-shape bulge; relatively long setae sparsely scattered over ventral surface of the genital segment; gonopods: first article fairly broad, bearing 8–10 moderately long setae, arranged in three irregular rows; with 2+2 moderately long and slender, coniform spurs, inner spur slightly smaller than the outer; second article with 5–6 long setae, arranged in two irregular rows; third article with 3–4 comparatively long setae, arranged in one or two irregular rows; third article with a simple apical claw (Fig. 1D).

Male S 15 posterior margin narrower than anterior, posteromedially straight, sparsely covered with long setae on the surface; sternite of genital segment smaller than in female, usually well sclerotized, posterior margin deeply concave between the gonopods, without medial bulge; long setae sparsely scattered on the ventral surface of the genital segment, fewer setae near S 15, fringed with longer setae along the posterior margin; gonopods short, appearing as a small hemispherical bulge, with 1–3 long setae, apically slightly sclerotized (Fig. 1E).

Habitat. The specimens here studied were collected in a mixed coniferous broad-leaved forest at ca 480–900 m above sea level, in moderately moist habitats under roadside stones and litter of the forest floor.

Table 2. The main morphological characters of the known Chinese species of subgenus *Ezembius* Chamberlin, 1919.

Characters	<i>anabilineatus</i>	<i>anasulcifemorialis</i>	<i>bidens</i>	<i>bilineatus</i>	<i>chekianus</i>	<i>datongensis</i>	<i>gantoensis</i>	<i>giganteus</i>	<i>insolitus</i>	<i>irregularis</i>
Authorities	Ma et al. 2015	Ma et al. 2013	Takakuwa 1939	Pei et al. 2014	Chamberlin and Wang 1952	Qiao et al. 2018	Takakuwa and Takashima 1949	Eason 1986	Eason 1993	Takakuwa and Takashima 1949
Distribution	China S (Guangxi)	China S (Guangxi)	China S (Taiwan)	China S (Guangxi)	China S (Zhengjiang and Taiwan)	China NW (Qinghai Province)	China NW (Shanxi)	China N (Inner Mongolia Autonomous region)	China S (Hong Kong)	China W (Shanxi)
Body length (mm)	11.9–12.1	10.1–12.3	15.0	9.0–9.1	16.0	12.3–14.2	9.0	15.0–50.0	10.0–11.5	12.0
Number of antennal articles	23+23; articles in female, unknown in male	19+19–24+24, commonly 20+20	20–21	two specimens with 20+21, one specimen with 20+23	20+20	20+20	20–23	20+20	18+18 – 19+19	20+20
Number, arrangement and shape of the ocelli	5–6, in 2 rows	6, in 3 rows	7	5–6, in 2 rows	5, in 3 rows	10, in 3 rows	6	6–10, in 2–3 rows	6–8, in 2 rows	7, in 2 rows
Posterior ocellus	round, large	oval to round, large	comparatively large	oval to rounded	oval to round, comparatively large	comparatively large	oval to round, comparatively large	oval to round, comparatively large	oval to round, comparatively large	round, comparatively large
Seriate ocelli	subequal, all ocelli domed, translucent, usually darkly pigmented	one near ventral margin moderately small, others almost equal	not reported	subequal, all ocelli domed, translucent, usually darkly pigmented	not reported	not reported	comparatively large	oval to round, comparatively large	not reported	subequal
Tömösváry's organ	round, smaller than adjoining ocelli	moderately large, rounded, slightly larger than adjoining ocelli	at most same size as one ocellus	slightly larger than adjoining ocelli	not reported	slightly larger than nearest ocellus	subequal in size to adjoining medium large ocelli	slightly smaller than adjoining ocelli	slightly smaller than adjoining ocelli	same size as largest ocellus
Number and arrangement of coxosternal teeth	2+2, subtriangular	2+2, moderately blunt	2+2	2+2, slightly triangular	2+2	2+2 slightly acute	2+2, approximately sharp, small	2+2	2+2, approximately sharp, small	2+2, small
Porodont	long, lying posterolateral to lateral-most teeth	slender, lying posterolateral to lateral-most tooth, their base moderately bulged	moderately long	thick and long, lying posterolateral to lateral-most tooth	not reported	setiform porodons separated from lateral tooth laterally	not reported	not reported	slender, lying posterolateral to lateral tooth, their base slightly bulged	long, their base slightly bulged
Tergites	smooth, backside slightly hunched	smooth	not reported	smooth, slightly hunched behind	not reported	almost smooth	smooth, without wrinkles	smooth, with slightly wrinkles	T1 smooth, other with wrinkles	smooth
Number of coxal pores	3–5, female 4454, 3554; male 4443, 4453	3–6, usually 4663, 5654, 5553, 5563 and 5565	5(6)555	usually females 4554, 5565; males 4553, 4454	6655 or 7665	4655 and 5575; Coxal pores 4654 and 4554 in male	3333	3333, 4554, 4555, 4565, 5565 or 5566	3–6, male 3443; female 4454, 4555, 5555, 5565	3–10, female 3–6 in 12 th leg, 4–6 in 13 th leg, 7–10 in 14 th and 15 th leg
Shape of coxal pores	round or slightly ovate	round or slightly ovate	round	ovate	not reported	rounded	round	round	round	round

Characters	<i>anabilineatus</i>	<i>anasulcifemorialis</i>	<i>bidens</i>	<i>bilineatus</i>	<i>chekianus</i>	<i>datougensis</i>	<i>gantoensis</i>	<i>giganteus</i>	<i>insolitus</i>	<i>irregularis</i>
Tarsus 1–tarsus 2 articulation on legs 1–13	not well-defined	not well-defined	Well-defined	not well-defined	not reported	distinct	not reported	Well-defined	not defined	Well-defined
Male 1 st leg	Obvious, thicker and stronger than other legs	markedly thicker and stronger than 1–13 legs, thicker and stronger than female	not reported	distinctly thick and strong	not reported	not reported	not reported	not reported	distinctly thick and strong	not reported
Male 15 th leg	obvious thicker and stronger than other legs	markedly thicker and stronger than 1–13 legs, thicker and stronger than female	not reported	distinctly thick and strong	not reported	not reported	not reported	not reported	distinctly thick and strong, with dark zones on dorsal of tibia	not reported
Dorsal sulci on male 14 th legs	absent	absent	not reported	with two, shallow longitudinal sulci	not reported	not reported	not reported	not reported	absent	not reported
Dorsal sulci on male 15 th legs	two distinct, shallow, dorsal sulci on femur and tibia	with a distinct, shallow, dorsal sulci on tibia	not reported	with two, shallow longitudinal sulci	not reported	not reported	not reported	not reported	absent	not reported
DatC spine	on 14 th –15 th legs	on 14 th –15 th legs	absent	on 4 th –15 th legs	on 14 th –15 th legs	on 12 th –15 th	absent	on 12 th –15 th legs (on 11 th and 12 th legs sometimes present)	absent	on 13 th –15 th legs
14 th accessory spur	anterior accessory spur reduced in size, only half length of posterior accessory spur	absent	not reported	anterior accessory spur absent	present	present	present	present	not reported	not reported
15 th accessory spur	absent	absent	not reported	anterior accessory absent	present	anterior accessory absent	present	absent	absent	not reported
Number and shape of spurs on female gonopods	2+2 moderately small, blunt, coniform spurs, inner spur slightly smaller than the outer	2+2 moderately blunt, with conical spurs, inner spur slightly smaller than the outer	3+3 or 4+4, sharp	2+2 moderately small, blunt, coniform spurs, inner spur slightly smaller than outer one	not reported	2+2 moderately large, coniform spurs	1+1, conical spurs	2+2	3+3, coniform spurs	2+2 or 2+3, moderately small, blunt, coniform spurs
Dorsal side of second article of female gonopods	with one spine lying dorsally on its external margin	no striking features	not reported	with three short, robust setae lying dorsally on its external margin	not reported	5-6 setae and five long curved spines	not reported	with eight spines in two irregular rows lying dorsally on its external margin	not reported	not reported
Apical claw of female gonopods (and lateral denticles)	simple, small subtriangular teeth in the inner	apical claw dimidiolate	simple, small sharply teeth in the inner	apical claw bipartite, and its inner aspect broader	not reported	undivided, bearing a small triangular protuberance on ventral side	simple	simple	simple	simple and broad
Male gonopods	short and small bulge, with one to two long setae, apically slightly sclerotised	with a small bulge, without setae and apically less sclerotised	hemispherical, with two long setae	short and small bulge, having a long seta, apically slightly sclerotised	not reported	a hemispherical bulge, with three setae	not reported	not reported	not reported	not reported

Table 2. (Continued) The main morphological characters of the known Chinese species of subgenus *Ezembius* Chamberlin, 1919.

Characters	<i>laevidentata</i>	<i>longibasiotarsus</i>	<i>lineatus</i>	<i>mandschuriensis</i>	<i>multispinipes</i>	<i>parvicornis</i>	<i>rhysus</i>	<i>sulcipes</i>	<i>subcylindromorpha</i>	<i>ternidentatus</i>	<i>zhui</i>	<i>tetrastriatus</i>
Authorities	Pei et al. 2015	Qiao et al. 2018	Takakuwa 1939	Takakuwa 1940	Pei et al. 2016	Zapparoli 1991	Attems 1934	Attems 1927	Takakuwa and Takashima 1949	This paper	Pei et al. 2011	Pei et al. 2018
Distribution	China NW (Xinjiang Uygur)	China NW (Qinghai)	China S (Taiwan)	China (Taiwan, Sichuan, Jiangsu, Hainan, Jilin, Liaoning)	China NW (Xinjiang Uygur)	China S (Taiwan)	China S (Fujian and Taiwan)	China S (Taiwan)	China W (Shanxi)	China N (Hebei)	China NW (Xinjiang Uygur)	China NW (Xinjiang Uygur)
Body length (mm)	9.6–13.3	17.0–18.0	18.0	22.0–23.0	11.6–22.6	16.0	15.0	Not reported	12.0	7.1–8.5	8.1–15.0	9.6–13.3
Number of antennal articles	19+19–21+21 commonly 20+20	20+20	19+19–21+21	20–28	commonly 20+20, (three specimens with 20+21, one specimen with 20+26 of 134 specimens)	20+20, 21+21	20+21 in female, 20+21 in male	19–22	20+20	22–25	20–24, commonly 20	19–22, commonly 20
Number, arrangement and shape of the ocelli	8–10, in 3 rows	11, in 3 rows	8–11, in 3 rows	9–13, in 3 rows	8, in 3 rows	3–4, in 1 or 2 rows	8, in 4 rows	7, in 2 rows	6	5–6, in 2 rows	10–13, in 3–4 rows	8–10, in 3 rows
Posterior ocellus	posterior two ocelli bigger than seriate ocelli	posterior ocellus largest	comparatively small	comparatively large	two ocelli large, oval to rounded	comparatively large	comparatively large	comparatively large	all ocelli same size	posterior two ocelli comparatively large	comparatively large	two ocelli comparatively large
Seriate ocelli	other seriate ocelli slightly larger than ocelli adjoining ventrally	not reported	not reported	same size	two near ventral margin moderately small, others almost equal	not reported	not reported	not reported	same size	others subequal in size	dorsal ones moderately large, those near ventral margin of ocellar field moderately small, others of moderate size	the adjoining Tomosvary organ slightly small
Tomosvary's organ	subequal in size to adjoining ocelli	smaller than adjacent ocelli	same size as adjoining ocelli	larger than adjoining ocelli	slightly smaller than adjoining ocelli	not reported	not reported	not reported	same size as ocelli	about same size as largest ocellus	slightly larger than adjoining ocelli	subequal in size to adjoining ocelli
Number and arrangement of coxosternal teeth	2+2, approximately blunt	3+2 blunt nipple-like teeth	2+2, comparatively large	2+2, small and sharp	3+3, slightly triangular	2+2	2+2	2+2	2+2, small and sharp	3+3 acute triangular, very few 2+2 or 2+3	2+2 moderately small and pointed	2+2 subtriangular slightly acute

Characters	<i>laevidentata</i>	<i>longibasiotarsus</i>	<i>lineatus</i>	<i>mandschuriensis</i>	<i>multispinipes</i>	<i>parvicornis</i>	<i>rhyus</i>	<i>sulcipes</i>	<i>sulcifemorialis</i>	<i>ternidentatus</i>	<i>zhui</i>	<i>ternaspinus</i>
Porodont	thick and long, lying posterolateral to lateral-most teeth	thick and strong separated from lateral tooth ventrolaterally	long and strong	lying posterolateral to lateral-most tooth	thick and long, lying posterolateral to lateral-most tooth	lying posterolateral to the lateral-most teeth	not obvious	not reported	slender and long	slender, lying posterolateral to, and separated from, lateral-most tooth	moderately thick in basal, moderately pointed, just posterolateral to lateral tooth	thick and strong, just posterolateral and separated from lateral tooth
Tergites	smooth, without wrinkles, backside slightly hunched	all smooth, without wrinkles	smooth	smooth, without wrinkles	smooth, without wrinkles and slightly hunched behind	smooth	with shallow wrinkles	Smooth, posterior angles slightly triangular in T14	not reported	smooth, without wrinkles, dorsum slightly convex	smooth, without wrinkles, backside slightly hunched	smooth, without wrinkles, dorsum slightly convex
Number of coxal pores	2–5, female commonly 4555, 4554, sometime 3454, 3455, 3343, male commonly 2332, 2333, sometime 3444, 3333	6555	6–7, usually 66(7)6	776(7)5(6)	3–5, 4555, 5555, 4444, 4455 (females) and 4444, 3344 (males)	3334	6554	4554	5555	3–3(4)–4(5)–3, commonly 3–4–3	2–4, 3444, 3344, 3443, 3333 in female, and 3443, 2343, 2433, 2332, 2333, rarely 3444, 3333 in males	usually 4555, 4554, rarely 3454, 3455, 3343 in females and usually 2332, 2333, rarely 3444, 3333 in males
Shape of coxal pores	round or slightly ovate	circular	round to ovate	round or ovate	round to ovate	not reported	round	round	round	round to slightly oval	round or slightly ovate	round or slightly oval
Tarsus 1–tarsus 2 articulation on legs 1–13	not well-defined	well-defined	well-defined	well-defined	well-defined	not reported	not reported	well-defined	well-defined	ill-defined	well-defined	ill-defined
Male 14 th leg	remarkably thicker and stronger	moderately thicker and longer	not reported	not reported	thick and strong	not reported	not reported	not reported	thick and strong	moderately thicker and longer	moderately thicker and stronger	significantly thicker and stronger
Male 15 th leg	markedly thicker and stronger	moderately thicker and longer	not reported	not reported	thick and strong	not reported	femur and tibia thicker	femur and tibia thicker	thick and strong	moderately thicker and longer	thicker and stronger, with a circular protuberance on distal end of tibia	significantly thicker and stronger
Dorsal sulci on male 14 th legs	absent	absent	absent	not reported	absent	not reported	not reported	present on femur	present on femur and tibia	absent	absent	absent
Dorsal sulci on male 15 th legs	with a distinct, shallow, dorsal sulci on the tibia	absent	not reported	not reported	absent	not reported	not reported	present on femur and tibia	present on femur and tibia	absent	absent	present on femur

Characters	<i>laevidentata</i>	<i>longibasiarsus</i>	<i>lineatus</i>	<i>mandschrensis</i>	<i>multispinipes</i>	<i>parvicornis</i>	<i>rhynus</i>	<i>sulcipes</i>	<i>sulcifemorialis</i>	<i>ternidentatus</i>	<i>zhui</i>	<i>terraspinus</i>
DaC spine	on 12 th –15 th legs	on 13 th –15 th legs, 12 th sometimes present	on 14 th –15 th legs	on 12 th –15 th legs	on 11 th –15 th legs, 9 th –10 th sometimes present	not reported	on 15 th legs present	on 15 th legs present	absent	on 10 th –15 th legs	on 13 th –15 th legs, 12 th sometimes present	on 12 th –15 th legs
14 th accessory spur	present	present	present	not reported	present	not reported	not reported	not reported	not reported	anterior accessory spur absent	present	present
15 th accessory spur	anterior absent	absent	present	not reported	absent	not reported	absent	not reported	not reported	anterior accessory spur absent	absent	absent
Number and shape of spurs on female gonopods	3+4, or 4+4 small, blunt, coniform spurs, commonly with 3+3, inner spur smaller than outer one	2+2 moderately long, bullet-shaped spurs, inner spur slightly smaller and more anterior than outer one	3+3 moderately sharp, slender conical spurs	3+3, same size	2+2, blunt, coniform spurs, with inner spur smaller than outer one	2+2	2+2, slender	2+2, thick spurs	2+2, strong, long and sharp	2+2 moderately long and slender, coniform	2fl 2 moderately long, coniform spurs, inner spur slightly smaller and more anterior than outer	3+3, few 3+4, only one 4+4 coniform spurs
dorsal side of the second article of female gonopods	with three long setae lying dorsally on its anterior external margin	three long setae along dorsolateral ridge	not reported	not reported	with 3–4 long setae and 5–6 spines lying dorsally on its external margin	not reported	not reported	not reported	not reported	no setae and spines	three spurs arranged in one irregular row on dorsal terminal part	3 long setae and four short, robust spines lying dorsally on posterior part of external margin
Apical claw of female gonopods (and lateral denticles)	simple and broad	simple, having small triangular protuberance on ventral side	simple	simple	simple	simple	simple	dimidiate	simple	simple	broad, and tridentate	simple, with a very small subtriangular blunt denticle on inner margin
Male gonopods	small bulge, with one to two long setae apically slightly sclerotised	small, semicircular article with 3–5 setae on its surface	hemispherical bulge,	without setae	hemispherical bulge, having a long seta, and apically slightly sclerotised	not reported	not reported	not reported	not reported	short, small hemispherical bulge, with 1–3 long setae, apically slightly sclerotised	small bulge, with 1–2 long setae on surface, and terminal slightly sclerotised	small hemispherical bulge, with 1–2 long setae

Etymology. The specific name *ternidentatus* refers to the coxosternite anterior margin with 3+3 slightly acute triangular teeth.

Discussion. The new species resembles *L. (E.) multispinipes* Pei, Lu, Liu Hou, Ma & Zapparoli, 2016 from the Xinjiang Autonomous Region in having 3+3 prosternal teeth commonly, the posterior two ocelli comparatively large, coxal pores 3–5 and with two coniform spurs on female gonopods. However, the new species can be easily distinguished by the following characters: the Tömösváry's organ about same size as the largest ocellus in contrast to slightly smaller than the adjoining ocelli in *L. (E.) multispinipes*; and with five or six ocelli in new species instead of eight ocelli in *L. (E.) multispinipes*; and tarsal articulation ill-defined on legs 1–13 in the new species in contrast to well-defined on legs 1–13 in *L. (E.) multispinipes*; and legs 14 posterior accessory spur absent versus present in *L. (E.) multispinipes*, moreover, the 14 legs ventral plectrotaxy are obviously different: 0-1-3-2-2 compared to 0-1-3-2-1 in *L. (E.) multispinipes*.

To assist in the identification of the Chinese species of *Lithobius (Ezembius)*, the main morphological characters (Table 2) of the known Chinese species of the subgenus *Ezembius* Chamberlin based on adult specimens are presented.

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First Mexican species of the genus *Cosberella* (Collembola, Hypogastruridae)

José G. Palacios-Vargas¹, Gabriela Castaño-Meneses²

1 *Ecología y Sistemática de Microartrópodos, Departamento de Ecología y Recursos Naturales, Facultad de Ciencias, UNAM, 04510, México, D. F., México* **2** *Ecología de Artrópodos en Ambientes Extremos, Unidad Multidisciplinaria de Docencia e Investigación, Facultad de Ciencias, UNAM, Campus Juriquilla, Boulevard Juriquilla 3001, 76230, Querétaro, México*

Corresponding author: Gabriela Castaño-Meneses (gabycast99@hotmail.com)

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Abstract

A new species of *Cosberella* is described and illustrated from a temperate forest of Citlaltépetl formation, Veracruz State. It is characterized by the following combination of characters: Th I with 2 + 2 dorsal setae; 2 + 2 axial setae on Th II–III; two capitate tenent hairs on each leg; unguiculus half the length of unguis; unguis with tooth; six dental setae and Abd VI without anal spines. A key for the species of the genus is included.

Keywords

Chaetotaxy, Citlaltépetl, intraspecific variation, taxonomy

Introduction

The genus *Cosberella*, was erected by Wray in 1963, and includes several species originally described in the subgenus *Mucrella* Fjellberg, 1985, and in *Hypogastrura* Bourlet, 1839 or *Achorutes* Templeton, 1835. All of them were transferred to the genus *Cosberella* by Bernard (2006) after a redescription of its type-species. It currently includes eight species distributed in the Holarctic and Nearctic regions. We have found a species new to science in the Neotropical region which is described here.

The abbreviations used in this paper are:

Ant	antennal segment;	PAO	postantennal organ;
a	anterior row of setae;	sgd	dorsal guard sensillum;
Abd	abdominal segment;	sgv	ventral guard sensillum;
m	median row of setae;	Th	thoracic segment.
p	posterior row of seta.		

Maxillary lamellae are numbered according to Fjellberg (1984).

Taxonomy

Cosberella Wray, 1963

Diagnosis. (after Bernard, 2006) Antenna with or without eversible sac between Ant III and IV. Six to eight sensilla on Ant IV. Ventral sensory file on Ant IV, when present, with 30 or fewer modified setae. Mandible with four or five apical teeth and well-developed molar plate. Maxilla with six lamellae, the fourth one reduced, not exceeding apex of the fifth one. Guard setae of labial palpus pointed; lateral process present or absent. Postantennal organ small, with four small distinct lobes, or simply oval with lobes indistinct; accessory tubercle absent. Unguis with or without tooth, tenent hairs acuminate or clavate. Unguiculus with or without lamella. Pronotum usually with 2 + 2, rarely with 3 + 3 setae. Ventral tube with 4 + 4 or 5 + 5 setae. Tenaculum with 4 + 4 teeth. Dens with six or seven setae, one proximal seta longer than others; mucro with a latero-external lamella of variable shape, its apex tapering, curved. Anal spines minute or absent.

Type species. *Cosberella conatoa* Wray, 1963.

Remarks. The Mexican species described here is assigned to the genus *Cosberella*. It recalls also the genus *Choreutinula* by the absence of anal spines and a small PAO with four flattened lobes. However, this genus lacks of unguiculus, or has only a short thin bristle in its place, while the unguiculus of the new species is well developed, straight and half as long as claw, and the fourth maxillary lamella is reduced, not exceeding apex of the fifth one, which are characteristics of genus *Cosberella*.

Cosberella mendozarum sp. n.

<http://zoobank.org/21837BAF-AF8F-4D66-B0C8-C3191DC0A69B>

Figs 1–8

Type-locality. México: Veracruz State (Atotonilco) 7 km from Parque Nacional del Pico de Orizaba. Pine-oak temperate forest, 19°08'30N, 97°12'26W, 2,225 m a.s.l. ex litter from pitfall traps, F. Álvarez leg.

Type-specimen. Holotype male mounted on slide. Original label: “21/2/12 México, Veracruz State, Pico de Orizaba, 2,225 m snm. F. Álvarez col. Pitfall 8” [printed label]. Collection number 22304.

Paratypes. 9 paratypes males and 1 juvenile mounted on slides, with the same data. Type material is kept at Colección de Microartrópodos, Facultad de Ciencias, UNAM. Collection numbers 22305–22314.

Diagnosis. Th I with 2 + 2 dorsal setae. Tenent hairs 2, 2, 2 in one whorl. Unguiculus without lamella and half the length of unguis. Unguiculus with a tooth in the apical third. Six dental setae, one proximal longer than others. Anal spines absent.

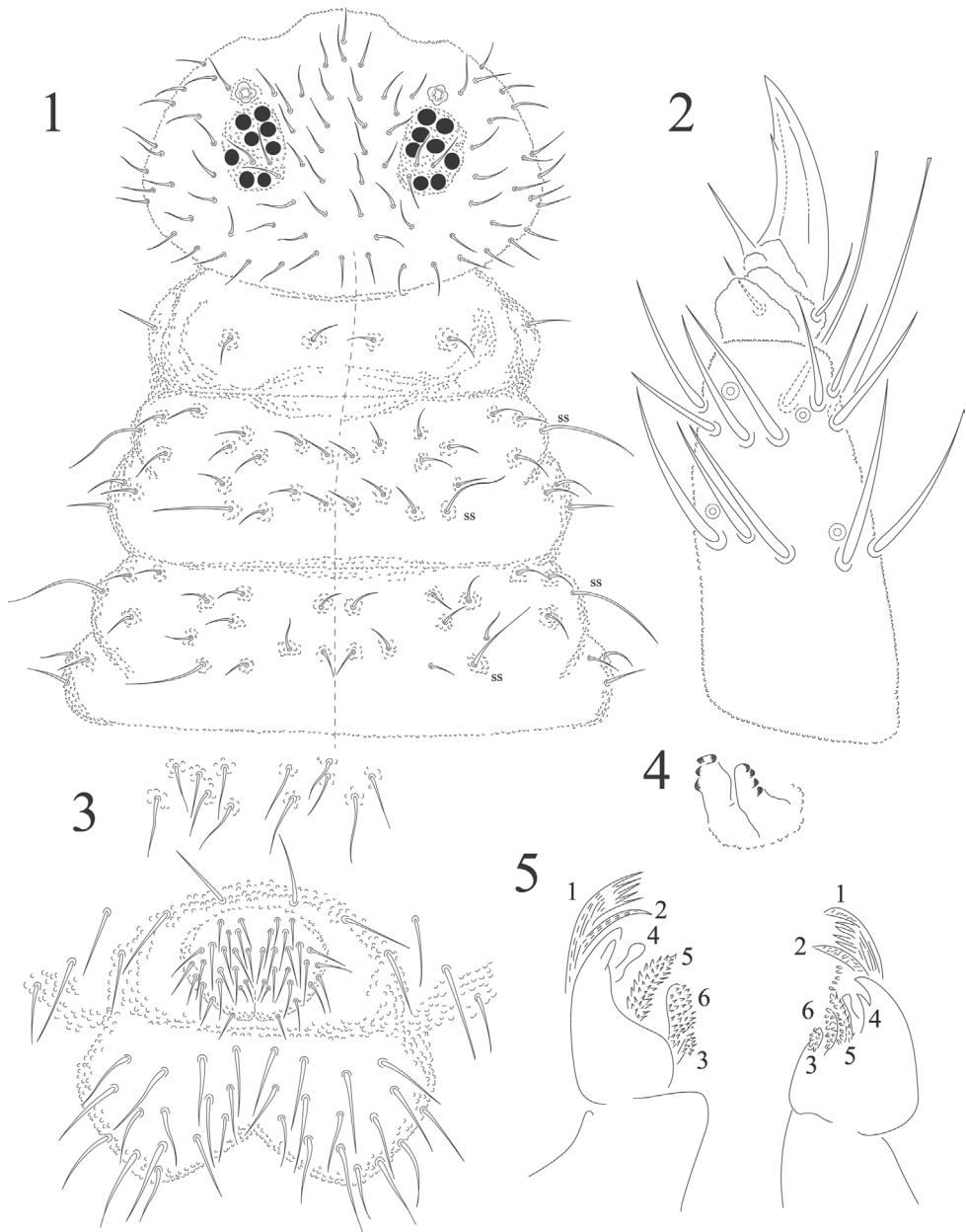
Description. Body length (average of 10 specimens) = 1.06 mm. Setae not differentiated in macro and microsetae, all of same size (Figs 1, 7), smooth and acuminate (6–8 μ m). Sensorial setae longer than regular setae (23–25 μ m). Sensorial formula as 022/11111. Color light blue in alcohol. Ratio head : antenna 1 : 0.7

Ant I with seven dorsal setae, Ant II with 12 setae. Ant III with 16 setae in two whorls, sense organ with two free club-shaped microsensilla, not covered by tegumentary fold; two long guard sensilla (sgd and sgv) of same shape and size, and one ventral microsensillum. No eversible sac between Ant III–IV. Ant IV with seven sensilla, subapical organite, lateral microsensillum and simple subapical bulb (Fig. 6), no sensory file on ventral side. Ratio Ant I: II; III; IV = 1:1.1; 1.4; 2.5.

Head with almost typical chaetotaxy for the genus but lacking seta c1. Three subequal setae in ocular area (Fig. 1). 8+8 eyes of about equal diameters. PAO made of one vesicle with a small tendency to be quadrangular, as big as closest eye. Labial palpus with six proximal setae; lateral process absent; maxillary palp normal for the genus; two pairs of postlabial setae. Mandible with 5–6 apical teeth, and normal molar plate. Maxilla with six lamellae. Lamella 1 with prominent apical denticles and dorsal minute medial denticles; lamella 2 very thin, ciliate; lamella 3 small, ciliate; lamella 4 reduced, not ciliate; lamella 5 densely ciliate; lamella 6 spherical and ciliate (Fig. 5). Th I with 2 + 2 dorsal setae and 1+1 lateral ones on upper subcoxae. Sensorial setae on Th II and III are m7 and p4 as usual. Each thoracic segment with 3 irregular rows of setae (Fig. 1) with m3 and m5 present; a2 present on Th II but lacking on Th III.

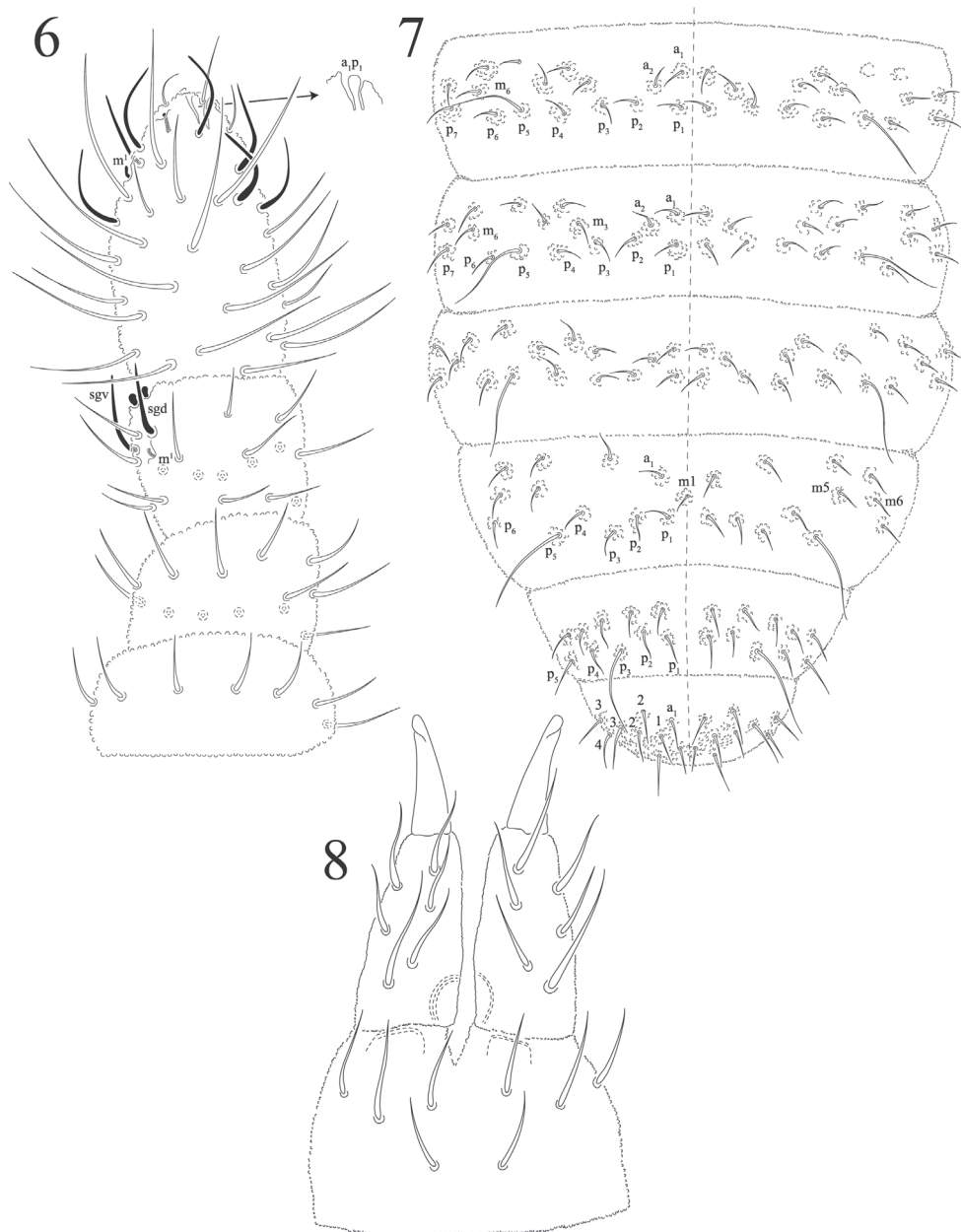
Leg chaetotaxy from I to III: coxae 5,5,7; trochanters 5,5,5; femora 12,11,10 with one ventral seta very long, as acuminate tenent hair; tibiotarsi 19,19,18 (Fig. 2); pretarsi 2,2,2. Two tenent hairs from slightly to clearly clavate on the dorso-distal whorl of each tibiotarsus. Unguis thick, curving slightly, with one ventral tooth in distal third (Fig. 2). Unguiculus straight, acuminate without any lamella. Ratio tibiotarsus/unguis = 1: 0.5.

Ventral tube with 4 + 4 or 5 + 5 setae. Tenaculum with 3–4+3–4 teeth, without seta on corpus (Fig. 4). Furcula well developed. Manubrium with ten pairs of setae, one of them longer. Dens dorsally with moderate granulation and with six setae, one basal longer than others, ventrally with a smooth triangular area less than $\frac{1}{4}$ of dens length. Mucro half-length of dens, not spoon-like, long and narrow with one very low outer lamella (not illustrated), apex curved (Fig. 8).



Figures 1–5. *Cosberella mendozarum* sp. n. **1** head and thorax chaetotaxy **2** tibiotarsus III **3** ventral chaetotaxy of Abd V and VI **4** tenaculum **5** maxillae.

Chaetotaxy of abdomen as in Fig. 7. Abd I - III with three irregular rows of dorsal setae, one sensorial seta at P5, except on Abd V where it is at P3. Number of axial setae from Abd I to III is 2 + 2. Abd IV with 3 + 3 such setae but half of the specimens lack one seta (as illustrated on Fig. 7). Abd VI with three rows of setae, a1–3, m1–4 pl-2,



Figures 6–8. *Cosberella mendozarum* sp. n. **6** Ant I–IV, dorsal view **7** dorsal abdominal chaetotaxy **8** furcula.

p0 displaced posteriorly. No anal spines. Genital plate of male with 3 + 3 pregenital, 38–44 circumgenital and 4 + 4 eugenital setae (Fig. 3). Each anal valve with 15 regular + 3 hr setae. Female unknown.

Etymology. The new species is named after professors Concepción and Enrique Mendoza from the high school “6”, of the UNAM, “Antonio Caso”, for their assistance provided to the senior author during his studies.

Discussion. The new species has an isolated position in the genus due to the combination of a number of characters, some of which are observed in other genera of Hypogastruridae, particularly in the genus *Choreutinula* (thoracic chaetotaxy, number of tibiotarsal tenent hairs, lanceolate unguiculus, complete absence of AS). Nevertheless, the structure of maxillary head with a partial reduction of the fourth lamella (main diagnostic trait of the genus *Cosberella*) unequivocally points to this genus as a better choice.

The new species is most similar to *C. arborea* (Fjellberg, 1992), the only other known species of the genus lacking anal spines. *Cosberella mendozarum* sp. n. can be easily distinguished by its specific chaetotaxy, first of all by the absence of cephalic seta c1, the presence of only 2+2 axial setae on Th II–III (vs 3+3 setae in *C. arborea*), the number of tibiotarsal tenent hairs on mid-leg (2 vs. 3 in two different whorls in *C. arborea*), the number of dental setae (6 subequal vs. 7 of different size in *C. arborea*), and the setae as microsetae, contrary to *C. arborea* which has one macroseta on each side of head and laterally (p6) on each abdominal segment from I to IV. *Cosberella conatoa* (Wray, 1963) differs from the new species by its minute anal spines, the absence of unguis tooth, different number of tenent hairs and the unguiculus with a strong lamella.

Variations. Ten specimens were studied. They present several setal asymmetries dorsally on abdomen. Few also have duplicated setae in one abdominal alveolus, and in a couple of cases one or two bifid setae on each alveolus of abdominal segments. Two specimens had 2 + 1 postlabial setae (instead of 2 + 2); PAO sometimes had 5 vesicles with a central part in circle, looking as a small flower. In four specimens retinaculum had 3 + 3 teeth instead of 4 + 4. Setae m1 on Abd IV vary asymmetrically, with a single seta on right or left side (normal axial number is 3 + 3). One specimen subadult had the posterior row of setae on Abd V with left side lacking sensorial setae, p1 and p2. Ventral tube had 5 + 5 setae (4 specimens), 4 + 4 (3 specimens), 5 + 6 (1 specimen), 5 + 3 (1 specimen) and 5 + 0 (1 specimen).

Key to species of *Cosberella*

- 1 With true and well developed anal spines.....2
- Without anal spines or very weakly developed7
- 2 Anal spines about 2/3 inner edge of hind unguis (in non-ecomorphic specimens)3
- Anal spines no more than ½ inner unguis.....4
- 3 Anal spines much longer than basal papilla. Ant IV ventral file with 20 – 30 setae (France)*C. acuminata* (Cassagnau, 1952)
- Anal spines about as long as basal papillae. Ant IV ventral file with 10 setae (Tuva, Siberia) *C. yoshiana* (Babenko, 2000)

- 4 Ant IV apical bulb trilobed, ventral file with about 30 setae (Tennessee, USA) ***C. lamaralexanderi* Bernard, 2006**
- Ant IV apical bulb simple to trilobed, ventral field with less than 16 setae **5**
- 5 Body setae long, macrosetae strongly developed. Abd IV with p_1 twice the length of p_2 (northern Russia) ***C. navicularis* (Schött, 1893)**
- Body setae short, most of them microsetae. Abd IV with p_1 less than twice as long as p_2 **6**
- 6 Maxillary lam 6 covered with denticles. Ventroapical hyaline field of dens short, only 1/4–1/3 of dens (Alaska, USA) ***C. denali* (Fjellberg, 1985)**
- Maxillary lam 6 with 3–4 apical hooks only. Ventroapical hyaline area large, occupying approx. 1/2 of dens (Indiana, USA) ***C. hibernica* (Fjellberg, 1987)**
- 7 Unguiculus about 2/3 as long as unguis, with broad basal lamella **8**
- Unguiculus about 1/2 as long as unguis, straight, acuminate without any lamella (Veracruz, México) ***C. mendozarum* sp. n.**
- 8 Tibiotarsi without tenent hairs, minute anal spines (Tennessee, USA) ***C. conatoa* (Wray, 1963)**
- Tibiotarsi with 2–3–2 tenent hairs (Vancouver, Canada) ***C. arborea* (Fjellberg, 1992)**

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Fernando Álvarez (UNAM) donated Collembola from pitfall samples he collected at Veracruz State. Elsa Coronado isolated the samples and made slides of *Cosberella* under the supervision of Arturo García. Elihú Catalán made the illustrations using a phase contrast microscope, and María Martínez prepared the final illustration plates. Drs Anatoly Babenko, Dariusz Skarżyński, and Louis Deharveng provided invaluable suggestions to improve the manuscript.

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A new unique leafhopper genus of Erythroneurini from Thailand, with the description of one new species (Hemiptera, Cicadellidae, Typhlocybinae)

Yuehua Song¹, Can Li²

1 School of Karst Science, Guizhou Normal University/ State Engineering Technology Institute for Karst Desertification Control, Guiyang, Guizhou 550001, China **2** Guizhou Provincial Key Laboratory for Rare Animal and Economic Insect of the Mountainous Region, Guiyang University, Guiyang, Guizhou 550005, China

Corresponding author: Can Li (lican790108@163.com; songyuehua@163.com)

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Abstract

A new genus of the leafhopper tribe Erythroneurini (Cicadellidae, Typhlocybinae) from Thailand, *Undulivena* **gen. n.**, and a new species *Undulivena thaiensis* **sp. n.**, are described and illustrated. The new genus exhibits a unique feature of the forewing venation with CuA vein strongly sinuate.

Keywords

Auchenorrhyncha, Homoptera, morphology, new taxa, taxonomy

Introduction

Erythroneurini Young (1952) is the largest tribe in the subfamily Typhlocybinae. The tribe is particularly diverse in Southeast Asia where many genera and species remain to be described. In this study, a new genus from Thailand, similar to *Salka* Dworakowska, 1972, is described based on its unique strongly sinuate CuA vein in the forewing

Materials and methods

Morphological terminology used in this work follows Dietrich (2005). Habitus photographs were taken using a Canon EOS 5D Mark II camera and the Camlift V2.7.0 software. Multiple photographs of each specimen were compressed into final images with Zerene Stacker (64-bit) software. Body length was measured from the apex of vertex to the tip of forewings. Abdomens were removed from specimens and cleared in cold 10% KOH solution overnight. The cleared material was rinsed with water and stored in glycerin. An Olympus SZX12 dissecting microscope was used for specimen study and Olympus BX41 and BX53 stereoscopic microscopes were used alternately for drawing of the dissected male genitalia and wings. The holotype of the new species is deposited at the Queen Sirikit Botanical Garden (QSBG), Chiang Mai, Thailand, and additional specimens examined are deposited at the Illinois Natural History Survey (INHS), Prairie Research Institute, University of Illinois at Urbana-Champaign, USA (UIUC), and the School of Karst Science (SKS), Guizhou Normal University, Guiyang, China.

Taxonomy

Undulivena gen. n.

<http://zoobank.org/A6F8BDA7-F19C-4529-808F-AB51C1C10B16>

Type species. *Undulivena thaiensis* sp. n.

Diagnosis. The new genus is quite different from the other genera of the tribe Erythroneurini in view of the forewing venation, patterns of patches and chaetotaxy of the subgenital plate. The CuA vein of forewing is waved, which is unique among known Erythroneurini.

Description. Body yellow to beige with dark brown markings.

Head in dorsal view roundly produced, somewhat narrower than pronotum. Vertex usually with large median apical spot; coronal suture present or indistinct. Face with frontoclypeus and anteclypeus relatively slender. Pronotum broad, with posterior margin concave. Scutellum almost entirely dark, with obvious transverse impression. Forewing with claval vein distinct; MP vein slightly curved, confluent with R vein basally; CuA vein strongly sinuate. Hind wing with RA vein present.

Male abdominal apodemes small, not exceeding 3rd sternite.

Male genitalia. Male pygofer lobe with posterior margin rounded, with one dorsal macrochaeta, several basolateral spine-like setae in distinct group and some similar scattered setae slightly more dorsally; dorsal appendage movably articulated basally, not extended beyond pygofer apex, connected with an extension of anal tube appendage articulated basally. Extension of anal tube appendage connected subbasally by ligament to sharp distal corners of aedeagal dorsal apodeme. Subgenital plate with few macrosetae laterally in basal half and numerous short stout setae on or near lateral and apical margin in lateral view. Style with 2nd extension long, with few basal teeth on outer margin; preapical lobe distinct. Connective Y-shaped, with

central lobe well developed. Aedeagal shaft very short, strongly laterally compressed, gonopore sub-apical on ventral surface; basal apodeme very short; preatrium well developed.

Distribution. Thailand.

Remarks. The new genus is very similar to *Salka* (from Oriental and Palearctic regions) in body shape and male genitalia, e.g., pygofer with dorsal appendages, long dorsal macrosetae and a group of basolateral macrosetae, and the presence of a median anterior lobe on the connective. It differs from *Salka* in having the venation of the forewing with CuA strongly sinuate, which is unique among known Typhlocybinae, and the subgenital plate with a few lateral macrosetae in basal half. The color pattern of the forewing is also very unusual with veins margined with yellowish white, contrasting with the dark wings.

Etymology. The new generic name combines the Latin words undula and vena, referring to the undulate vein for the sinuate CuA vein of the forewing. The gender is feminine.

***Undulivena thaiensis* sp. n.**

<http://zoobank.org/A27A32A4-3FB2-40E6-86A5-C72B638AE804>

Figs 1–22

Diagnosis. The forewing has yellow-whitish stripes along veins. The style apex expanded, with inner margin tooth-like medially, and the aedeagal shaft spindle-shaped in ventral view, with single small subbasal process.

Description. Crown yellow, with large irregular central blackish brown patch (Figs 3, 7). Eyes grey (Figs 2, 6). Face pale beige marked with brown on postclypeus laterally and on anteclypeus basally (Figs 4, 8). Pronotum whitish yellow with large patch medially and hind margin, blackish brown (Fig. 1). Scutellum blackish brown (Fig. 1). Fore wing dark brown with veins margined with yellow-white (Fig. 1).

Male abdominal apodemes short, not extending to hind margin of 3rd sternite (Fig. 12). Male genitalia as in generic description with male pygofer dorsal appendage tapered distally; extension of anal tube appendage hook-like apically (Figs 16, 23). Pygofer lobe with one dorsal macrosetae (Fig. 13). Subgenital plate with group of 4 macrosetae laterally in basal half (Figs 13, 14). Style with 2nd extension of apical process expanded at midlength thereafter tapered to acute apex (Fig. 17). Aedeagal shaft with single small subbasal tooth-like process on left side, shaft spindle-shaped in ventral view with sharp basal corners and pair of converging lateral flanges distally, dorsal surface distally keel-like (Fig. 19); dorsal apodeme small tapered to apex in lateral view and with two sharp distal corners connected with ligament to ventral pygofer process; preatrium moderately long (Figs 19, 20).

Hind margin of female 7th sternite convex medially (Fig. 9).

Measurements. Body length, males 3.2–3.3 mm, females 2.7–2.8 mm.

Specimens examined. Holotype: ♂, THAILAND, Kanchanaburi, Khuean Srinagarindra NP, Chong Kraborg, 14°29.972'N, 98°53.035'E 210m, Malaise trap,



Figures 1–11. *Undulivena thaiensis* sp. n. (♂): **1** habitus, dorsal view **2** habitus, lateral view **3** head and thorax, dorsal view **4** face. (♀): **5** habitus, dorsal view **6** habitus, lateral view **7** head and thorax, dorsal view **8** face **9** abdomen of female **10** forewing **11** hind wing.

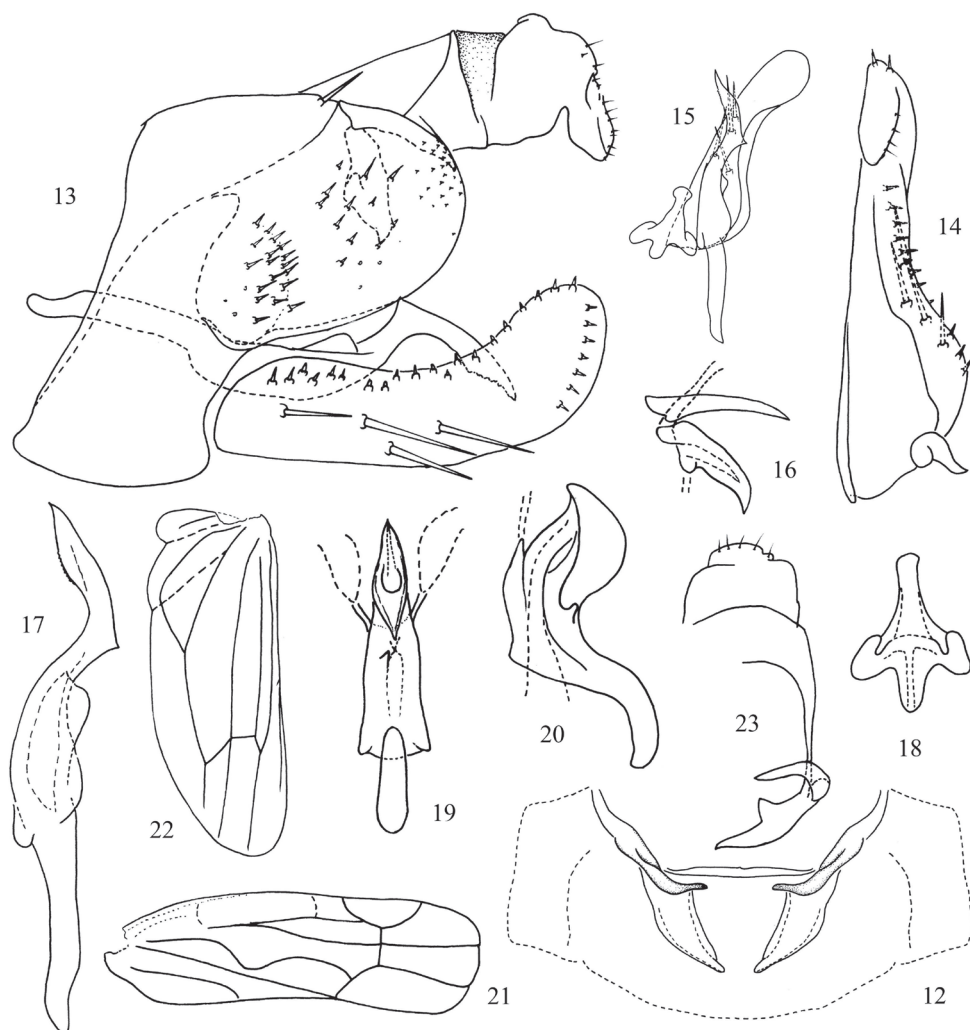
4–11.ix.2008, coll. Boonnam & Phumarin (QSBG). Paratypes: 3♂♂, 3♀♀, same data as holotype; 4♂♂, THAILAND, Kanchanaburi, Khuean Srinagarindra NP, Tha Thung-na/Chong Kraborg, 14°29.972'N, 98°53.035'E 210m, Malaise trap 6–13. xi.2008, coll. Boonnam & Phumarin (INHS, SKS).

Remarks. This species can be distinguished by external and male genitalia characters (see generic Remarks).

Etymology. The species is named for the type locality, Thailand. The name is adjectival.

Acknowledgements

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Figures 12–23. *Undulivena thaiensis* sp. n. **12** abdominal apodemes **13** genital capsule **14** subgenital plate **15** subgenital plate, style and connective **16** pygofer dorsal appendage (upper part) and an extension of anal tube appendage (lower part), lateral view **17** style **18** connective **19** aedeagus, ventral view (broken line indicates ligament attaching to pygofer dorsal appendage) **20** aedeagus, ventro-lateral view **21** venation of forewing **22** venation of hind wing **23** anal tube appendage with an apex extension and pygofer dorsal appendage, dorsal view.

Scholars of Guizhou Province ([2015]17), the Natural Science Research Project of Education Department of Guizhou Province ([2015]357), the Key Project of Natural Science Foundation of Science and Technology Department of Guizhou Province ([2018]1411), Guizhou Science and Technology Support Project ([2019]2855), and the Project for Regional Top Discipline Construction of Guizhou Province: Ecology in Guiyang University (Qian Jiao Keyan Fa [2017]85).

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First record of the genus *Fagineura* Vikberg & Zinovjev (Hymenoptera, Tenthredinidae) with descriptions of two new species from China

Mengmeng Liu^{1,2}, Zejian Li², Meikai Wei³

1 Lab of Insect Systematics and Evolutionary Biology, Central South University of Forestry and Technology, 498 South Shaoshan Road, Changsha 410004, Hunan, China **2** Lishui Academy of Forestry, Lishui 323000, Zhejiang, China **3** College of Life Science, Jiangxi Normal University, Nanchang 330026, Jiangxi, China

Corresponding author: Meikai Wei (weimc@126.com)

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Abstract

Fagineura Vikberg & Zinovjev, 2000 is recorded from China for the first time. Two species of *Fagineura* are described as new, *F. flactoserrula* sp. n. and *F. xanthosoma* sp. n. A key to the species of *Fagineura* worldwide is provided, now including four species. In addition, a simple phylogenetic analysis of *Fagineura* species is provided, based on sequences of the COI and NaK genes.

Keywords

COI, key, NaK, Nematinae, sawfly, Symphyta, taxonomy

Introduction

Fagineura Vikberg & Zinovjev, 2000 (Shinohara et al. 2000) is a very small genus of the subfamily Nematinae (Tenthredinidae). Until now, there are only two known species in the world (Taeger et al. 2010), namely *F. crenativora* Vikberg & Zinovjev, 2000 (type species) and *F. quercivora* Togashi, 2006, both of which are distributed in Japan. In a study of Nematinae from China, two species of *Fagineura* were found that are different from the two known species in Japan, and they are described herein as

new species. Additionally, the genus *Fagineura* is recorded as a new genus in China. The two species are described and illustrated, a key to the known species of *Fagineura* worldwide is provided, and a simple phylogenetic analysis based on DNA sequence data from two genes (COI and NaK) is provided.

Materials and methods

Imaging, terminology, deposition of material

The specimens were examined with a Motic-SMZ-171 stereomicroscope. Images of the imagines were taken with a Nikon D700 digital camera and a Leica Z16APO separately. The genitalia were examined with a Motic BA410E microscope, and images of the genitalia were taken with Motic Motacam Pro 285A. The series of images produced were montaged using Helicon Focus (HeliconSoft, Kharkiv, Ukraine) and further processed with Adobe Photoshop CS 11.0.

Morphological descriptions of the new species are based on the holotypes. The terminology of genitalia follows Ross (1945) and that of general morphology follows Viitasaari (2002). For a few terms, including middle fovea, lateral fovea, and lateral walls, we follow Takeuchi (1952).

Specimens examined in this study are deposited in the Central South University of Forestry and Technology, Changsha (CSCS), China, including all holotypes and paratypes of the two new species.

Phylogenetic analyses

DNA was extracted from adult samples stored in 99.5% ethanol at -20 °C by using the DNeasy Tissue Kit (Qiagen, Valencia, CA). Sequence data were obtained from the mitochondrial gene cytochrome oxidase I (COI; 810 bp) and the nuclear gene sodium-potassium adenosine triphosphatase (NaK; 952 bp). PCR amplification of COI and NaK were performed as described previously (Normark et al. 1999; Nyman et al. 2006; Leppänen et al. 2012). New sequences have been deposited in GenBank under accession numbers MH544099–MH544102. COI and NaK sequences of Nematinae species used in previous phylogenetic analyses are available in GenBank, and their accession numbers and references are shown in Table 1.

The data of each newly sequenced sample are as follows:

Fagineura flactoserrula sp. n.: Paratype, 1♀, China, Hubei Province, Yichang City, Shennongjia Mountain, Yinyuhe, 31°34'00"N, 110°20'22"E, 2100 m, 16 May 2012, leg. Zejian Li; the GenBank Accession Numbers of COI and NaK are MH544099 and MH544101, respectively.

F. xanthosoma sp. n.: Paratype, 1♀, China, Hubei Province, Yichang City, Shennongjia Mountain, Yinyuhe, 31°34'00"N, 110°20'22"E, 2100 m, 17 May 2012, leg. Zejian Li; the GenBank Accession Numbers of COI and NaK are MH544100 and MH544102, respectively.

Table 1. COI and NaK sequences of Nematinae species analyzed in this work.

Species Name	GenBank Accession Number		Reference
	COI	NaK	
<i>Anoplonyx apicalis</i>	DQ302172	KJ434879	Nyman et al. (2006), Prous et al. (2014)
<i>Caulocampus acericaulis</i>	DQ302182	KJ434873	Nyman et al. (2006), Prous et al. (2014)
<i>Craterocercus fraternalis</i>	DQ302170	KJ434878	Nyman et al. (2006), Prous et al. (2014)
<i>Endophytus anemones</i>	DQ302186	KJ434900	Nyman et al. (2006), Prous et al. (2014)
<i>Euura amerinae</i>	KJ434923	KJ434915	Prous et al. (2014)
<i>Euura annulata</i>	DQ302195	KJ434876	Nyman et al. (2006), Prous et al. (2014)
<i>Euura dimmockii</i>	DQ302192	KJ434885	Nyman et al. (2006), Prous et al. (2014)
<i>Euura dolichura</i>	DQ302213	KJ434858	Nyman et al. (2006), Prous et al. (2014)
<i>Euura herbaceae</i>	DQ302217	KJ434860	Nyman et al. (2006), Prous et al. (2014)
<i>Euura imperfecta</i>	DQ302210	KJ434883	Nyman et al. (2006), Prous et al. (2014)
<i>Euura lanatae</i>	DQ302219	KJ434907	Nyman et al. (2006), Prous et al. (2014)
<i>Euura leucapsis</i>	KJ434922	KJ434909	Prous et al. (2014)
<i>Euura lipovskyi</i>	DQ302206	KJ434892	Nyman et al. (2006), Prous et al. (2014)
<i>Euura melanaspis</i>	DQ302205	KJ434863	Nyman et al. (2006), Prous et al. (2014)
<i>Euura miliaris</i>	DQ302207	KJ434895	Nyman et al. (2006), Prous et al. (2014)
<i>Euura montana</i>	DQ302193	KJ434868	Nyman et al. (2006), Prous et al. (2014)
<i>Euura pumilio</i>	DQ302190	KJ434882	Nyman et al. (2006), Prous et al. (2014)
<i>Euura ribesii</i>	DQ302208	KJ434871	Nyman et al. (2006), Prous et al. (2014)
<i>Euura saliciscinereae</i>	DQ302216	KJ434859	Nyman et al. (2006), Prous et al. (2014)
<i>Euura scutellata</i>	DQ302191	KJ434866	Nyman et al. (2006), Prous et al. (2014)
<i>Euura venusta</i>	DQ302220	KJ434862	Nyman et al. (2006), Prous et al. (2014)
<i>Fagineura crenativora</i>	DQ302233	KJ434899	Nyman et al. (2006), Prous et al. (2014)
<i>Fagineura flactoserrula</i>	MH544099	MH544101	This work
<i>Fagineura xanthosoma</i>	MH544100	MH544102	This work
<i>Fallocampus americanus</i>	DQ302178	KJ434903	Nyman et al. (2006), Prous et al. (2014)
<i>Kerita fidala</i>	KJ434918	KJ434826	Prous et al. (2014)
<i>Mesoneura opaca</i>	DQ302169	KJ434877	Nyman et al. (2006), Prous et al. (2014)
<i>Mesoneura shishikuensis</i>	KY698135	KY698259	Prous et al. (2017)
<i>Nematus erythrogaster</i>	KJ434917	KJ434818	Prous et al. (2014)
<i>Nematus princeps</i>	KJ434921	KJ434865	Prous et al. (2014)
<i>Nematus septentrionalis</i>	DQ302197	KJ434875	Nyman et al. (2006), Prous et al. (2014)
<i>Nematus tulunensis</i>	DQ302209	KJ434872	Nyman et al. (2006), Prous et al. (2014)
<i>Priophorus pallipes</i>	DQ302167	KJ434890	Nyman et al. (2006), Prous et al. (2014)
<i>Pristiphora abbreviata</i>	KJ434920	KJ434848	Prous et al. (2014)
<i>Pristiphora abietina</i>	DQ302227	KJ434869	Nyman et al. (2006), Prous et al. (2014)
<i>Pristiphora alpestris</i>	DQ302228	KJ434897	Nyman et al. (2006), Prous et al. (2014)
<i>Pristiphora coactula</i>	DQ302229	KJ434870	Nyman et al. (2006), Prous et al. (2014)
<i>Pristiphora ferruginosa</i>	DQ302188	KJ434893	Nyman et al. (2006), Prous et al. (2014)
<i>Pristiphora geniculata</i>	DQ302225	KJ434898	Nyman et al. (2006), Prous et al. (2014)
<i>Pristiphora litura</i>	DQ302231	KJ434894	Nyman et al. (2006), Prous et al. (2014)
<i>Pristiphora monogyniae</i>	DQ302223	KJ434880	Nyman et al. (2006), Prous et al. (2014)
<i>Pseudodineura mentiens</i>	KJ434919	KJ434841	Prous et al. (2014)

The final two-gene alignment is 1762 base pairs long and contains 42 specimens from 13 genera. The genetic distances among species were calculated based on Kimura 2-parameter model of the two genes in Mega 7 (Kumar et al. 2016). Bayesian phylogenetic analyses were performed in MrBayes 3.2.6 (Ronquist et al. 2012). The dataset was not partitioned, and the best-fitting DNA substitution model for the two-gene alignment was selected using jModelTest 2.1.7 (Darriba et al. 2012), which uses PhyML (Guindon and Gascuel 2003) for likelihood calculations. Model selection was done by selecting among 11 substitution schemes (including 88 different models) on the basis of the Akaike Information Criterion (AIC).

Abbreviations used in the text and illustrations are as follows:

- OCL** The distance between a lateral ocellus and the occipital carina, or the hind margin of the head where this carina would be if it were developed (Benson 1954).
OOL The distance between an eye and a lateral ocellus.
POL The distance between the mesal margins of the 2 lateral ocelli.

Results

Taxonomy

Fagineura Vikberg & Zinovjev, 2000

Diagnosis. Medium-sized; clypeus and labrum yellowish-white to yellow; clypeus with broad and moderately deep (0.4–0.5) emargination apically; mandibles symmetrical; malar space shorter than diameter of median ocellus, and in most species not exceeding $0.5 \times$ of diameter of median ocellus; postocellar area short, more than $2.0 \times$ as wide as long; antenna usually shorter than thorax and abdomen together; posterior part of mesopleural katepimeron covered with hairs; distance between cenchri almost as long as breadth of a cenchrus; forewing without radial cross-vein; the costa of forewing less dilated than in *Pristiphora*; hindwing with anal cell petiolate; claws bifid, inner tooth large; sawsheath short; annular suture 1 with setae band; the longest setae bands of lancet is at least $0.5 \times$ length of annulus (Figs 1i, 2h); cypsella of basal serrulae almost absent, apically short and with somewhat deep emargination; tangium of lancet with campaniform sensilla in most species; radix at least $0.5 \times$ as long as lamnium, in most species radix not shorter than lamnium.

Remarks. The genus resembles *Pristiphora*, *Mesoneura*, *Euura* and *Nematus*, but *Fagineura* can be distinguished from *Pristiphora* by having an emarginate clypeus; less dilated costa of the forewing; claws with a large inner tooth; in males, the posterior end of tergum 8 with distinct apical projection; distinguished from *Mesoneura* by the lack of radial cross-veins; apex of vein C in forewing slightly enlarged; abdomen longer than the head and thorax together; ovipositor sheath longer than fore tibia; distinguished from *Euura* and *Nematus* by an annular suture 1 with setae band; malar space narrower than the diameter of the median ocellus; katepimeron of the mesopleuron with hairs; having campaniform sensilla on the tangium in most cases.

1 Terga 1–2 black; lancet 14–15 serrulae **2**
– Terga 1–2 yellow; lancet 19–21 serrulae..... **3**
2 Metapleuron pale yellowish; orbit yellowish to brownish in female; clypeus
emarginated for about 0.5 of its length; postocellar area $2.5 \times$ as wide as long;
ovipositor sheath with shallow emargination apically; cerci reaching further
back than sheath; annular suture 1 of lancet straight, and with 3 marginal
sensilla below. Japan (Hokkaido, Honshu, Kyushu, Shikoku)
..... ***F. crenativora* Vikberg & Zinovjev, 2000**
– Metapleuron mostly black (Fig. 1e); orbit black in female (Fig. 1b–c); clypeus
emarginated for about 0.3 of its length (Fig. 1c); postocellar area $3.0 \times$ as
wide as long (Fig. 1b); ovipositor sheath without emargination apically, cerci
almost as long as sheath (Fig. 1f); annular suture 1 of lancet narrower on
dorsal than on ventral side, with 7 marginal sensilla towards ventral side (Fig.
1i–j). China (Hubei) ***F. flactoserrula* sp. n.**
3 Mesepisternum entirely black; all coxae and apical 0.3 of hind tibia black;
terga 3–10 mostly black; ovipositor sheath black; malar space nearly absent;
petiole of anal cell of hindwing shorter than cu-a; tarsal claw with inner tooth
longer than outer tooth; lancet with 19 serrulae. Japan (Honshu)
..... ***F. quercivora* Togashi, 2006**
– Mesepisternum entirely pale yellowish-brown (Fig. 2d); all coxae and hind
tibia pale yellowish (Fig. 2a); terga 3–10 entirely pale yellowish-brown (Fig.
2a); ovipositor sheath yellow (Fig. 2g); malar space 0.8 times as long as
diameter of median ocellus (Fig. 2c); petiole of anal cell of hindwing longer
than cu-a (Fig. 2a); tarsal claw with inner tooth shorter than outer tooth;
lancet with 21 serrulae (Fig. 2i). China (Hubei, Hunan) .. ***F. xanthosoma* sp.**
n.

Fig. 1

Diagnosis. Body mostly black; labrum and clypeus pale yellow (Fig. 1b–c); most parts of mesepisternum yellowish-brown (Fig. 1e); most of stigma pale yellowish-brown but margins black brown, veins in most part black brown; labrum and clypeus smooth and shiny, with few faint setigerous punctures, without microsculpture; frons slightly shiny, with hair warts and few wrinkles, punctures minute and sparse (Fig. 1b–c); vertex and postocellar area shiny, punctures faint and sparse, without microsculpture; malar

space $0.5 \times$ as long as diameter of median ocellus; postocellar area slightly convex, without mesosulcus, approx. $3.0 \times$ as wide as long; relative length of antennomere 3 : antennomere 4 : antennomere 5 = 1.0 : 1.5 : 1.2 (Fig. 1d); forewings with cross-vein cu-a joining cell 1M at basal 0.5, cell 2Rs $1.2 \times$ as long as wide, petiole of anal cell of hindwing $1.6 \times$ as long as cu-a; lancet with 14 serrulae (Fig. 1i); annular suture 1 oblique and slightly curved, sutures 1–10 with setae bands, longest setae band about $0.7 \times$ length of annulus; tangium $3.4 \times$ as long as annulus 1, radix $1.1 \times$ as long as lamnium (Fig. 1j).

Description. Holotype, female. Body length approximately 6.5 mm (Fig. 1a).

Color. Body mostly black. Labrum, clypeus, most parts of pronotum, most parts of propleuron, tegula, most parts of all coxae, all trochanters and femora pale yellow; most parts of vertex and temple, triangular spot of median mesoscutal lobe and mesoscutellum, most parts of mesepisternum, speckles on terga, sterna of abdomen, all tibiae and tarsi yellowish-brown; valvifer 2 pale yellow, valvula 3 yellowish-brown to black; cenchrus yellowish-white. Wings hyaline, most parts of stigma pale yellowish-brown with margins black brown, veins in most part black brown.

Head. Inner margins of eyes slightly convergent downward in frontal view, distance between eyes $1.9 \times$ as long as height of eyes. Base of labrum elevated, apex slightly rounded; base of clypeus elevated, anterior margin of clypeus incised to $0.3 \times$ length of clypeus, lateral corners rounded; labrum and clypeus shiny, with few faint setigerous punctures, without microsculpture. Malar space $0.5 \times$ as long as diameter of median ocellus (Fig. 1c). Middle fovea long and groove-like, narrow and deep. Frons elevated, slightly shiny, with hair warts and few wrinkles, punctures minute and sparse; anterior wall slightly elevated and curved, notched medially, lateral walls low and blunt. Interocellar furrow broad and shallow, postocellar furrow slightly narrow and deep; circumocellar furrow indistinct; POL : OOL : OCL = 1.0 : 1.1 : 0.6 (Fig. 1b). Vertex and postocellar area shiny, punctures faint and sparse, without microsculpture; postocellar area slightly convex, without mesosulcus, approx. $3.0 \times$ as wide as long, lateral furrows broad and slightly deep, parallel; in dorsal view, inner margins of eyes slightly divergent (Fig. 1b). Antenna filamentous, antennomere 3 slightly compressed, slightly shorter than thorax and abdomen together; antennomere 2 $1.3 \times$ as wide as long, relative length of antennomere 3 : antennomere 4 : antennomere 5 = 1.0 : 1.5 : 1.2 (Fig. 1d).

Thorax. Mesonotum shiny, with fine and slightly dense punctures, without microsculpture; median mesoscutal groove shallow and thin; mesoscutellum shiny, with faint and sparse punctures, and flat, posterior half of middle ridge distinct, about $0.8 \times$ as long as wide; mesoscutellar appendage slightly shiny, with weak and sparse punctures, microsculpture faint, about $0.3 \times$ length of scutellum, middle ridge low and blunt. Distance between cenchri as long as breadth of a cenchrus. Mesepisternum smooth and shiny, setigerous punctures and microsculpture indistinct; anepimeron of mesepimeron slightly shiny, with few wrinkles, punctures faint; katepimeron shiny, most parts with microsculpture and posterior part distinct, punctures weak and very sparse, posterior part covered with few setae; metapleuron shiny and smooth, with few weak punctures, microsculpture indistinct (Fig. 1e). Vein Sc interstitial with origin of vein M from R, and vein M slightly shorter than

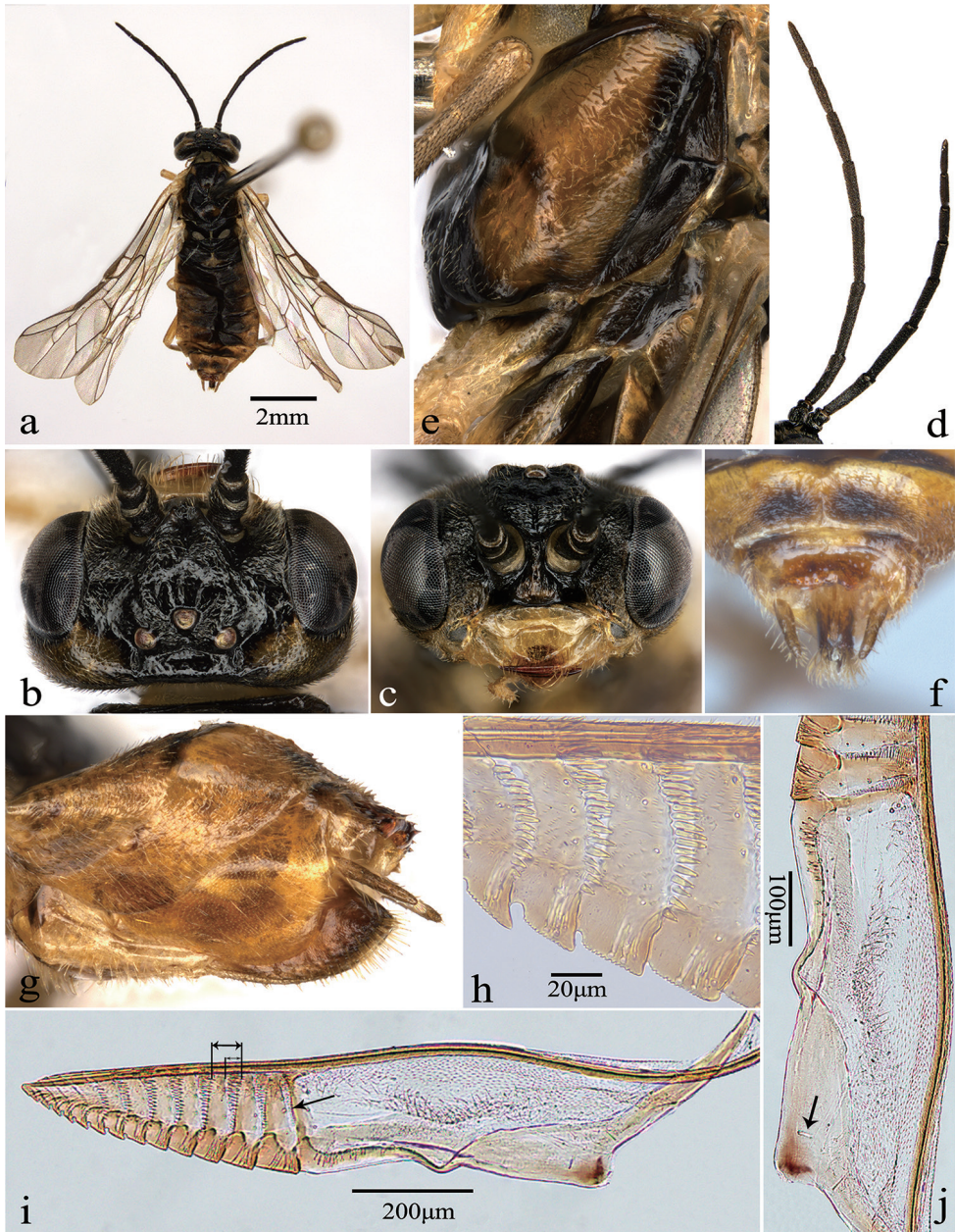


Figure 1. *Fagineura flactoserrula* sp. n., female, holotype. **a** Dorsal view **b** head, dorsal view **c** head, anterior view **d** antenna, lateral view **e** mesopleuron and metapleuron **f** ovipositor sheath, dorsal view **g** ovipositor sheath, lateral view **h** middle serrulae **i** lancet; the short double arrow denotes the longest setae band, the long double arrow denotes the length of the annulus, the simple arrow denotes the annular suture **j** tangium; the arrowhead denotes a single campaniform sensillum.

vein R+M; forewings with cross-vein cu-a joining cell 1M at basal 0.5, cell 2Rs $1.2 \times$ as long as wide, petiole of anal cell of hindwing $1.6 \times$ as long as cu-a.

Abdomen. All abdominal terga shiny, with faint sparse setigerous punctures, microsculpture fine and very dense. Ovipositor sheath smooth and shiny, punctures laterally on valvula 3 weak and sparse, microsculpture indistinct; sheath $2.0 \times$ as long as metatarsomere 1 and $1.3 \times$ as long as front tibia, valvula 3 as long as valvifer 2; in lateral view, sheath tapering toward apex (Fig. 1g); in dorsal view, apex of cercus protruding beyond valvula 3, angle between most lateral setae of valvula 3 about 60° (Fig. 1f). Lancet with 14 serrulae (Fig. 1i); each middle serrula with 10–13 distal teeth (Fig. 1h); annular suture 1 oblique and slightly curved, sutures 1–10 with setae bands, longest setae band about $0.7 \times$ length of annulus; cypsella of serrulae 1–5 nearly absent, cypsella of serrulae 6–12 short and deep; tangium $3.4 \times$ as long as annulus 1, with one campaniform sensillum (Fig. 1j), radix $1.1 \times$ as long as lamnium.

Legs. Protarsomere 1 shorter than combined length of tarsomeres 2–4; inner apical spur of hind tibia $0.4 \times$ as long as metatarsomere 1, metatarsomere 1 $0.6 \times$ as long as combined length of metatarsomeres 2–5; tarsal claw with inner tooth long, but slightly shorter than outer tooth.

Male. Unknown.

Distribution. China (Hubei).

Variation. Triangular spot on median mesoscutal lobe yellowish-brown to black-brown; mesoscutellum entirely black, or sometimes with yellowish-brown speckles; tangium with one campaniform sensillum, or none.

Remarks. The new species is similar to *F. crenativora* Vikberg & Zinovjev, 2000, but can be distinguished from the latter by the following characters: metapleuron mostly black; orbit black in the female; postocellar area $3.0 \times$ as wide as long; sheath without emargination apically; cerci almost as long as the sheath; lancet with 14 serrulae, annular suture 1 of lancet oblique and slightly curved, and with 7 marginal sensilla below.

Etymology. The specific name is derived from the flattened serrulae of the lancet.

Fagineura xanthosoma sp. n.

<http://zoobank.org/761893DD-B1DA-4A46-A692-85FF34DC7EAD>

Fig. 2

Type material. **Holotype**, ♀, **China**, Hubei Province, Yichang City, Shennongjia Mountain, Yinyuhe, $31^\circ34'00''\text{N}$, $110^\circ20'22''\text{E}$, 2100m, 17 May 2012, leg. Zejian Li, CSCS. **Paratypes** (15♀♀): 1♀, **China**, Hubei Province, Yichang City, Shennongjia Mountain, Yinyuhe, $31^\circ34'00''\text{N}$, $110^\circ20'22''\text{E}$, 2100 m, 17 May 2012, leg. Zejian Li; 1♀, **China**, Hunan Province, Wugang City, Yun Mountain, Television tower, $26^\circ38'38''\text{N}$, $110^\circ37'18''\text{E}$, 1380 m, 11 April 2012, leg. Zejian Li and Zaiyang Pan; 1♀, **China**, Hunan Province, Wugang City, Yun Mountain, 1100 m, 25 April 2005, leg. Yingke He; 8♀♀, **China**, Hunan Province, Yongzhou City, Yangming Mountain, 900 to 1000 m, 24 April 2004, leg. Shaobing Zhang; 3♀♀, **China**, Hunan Province, Yongzhou City, Yangming

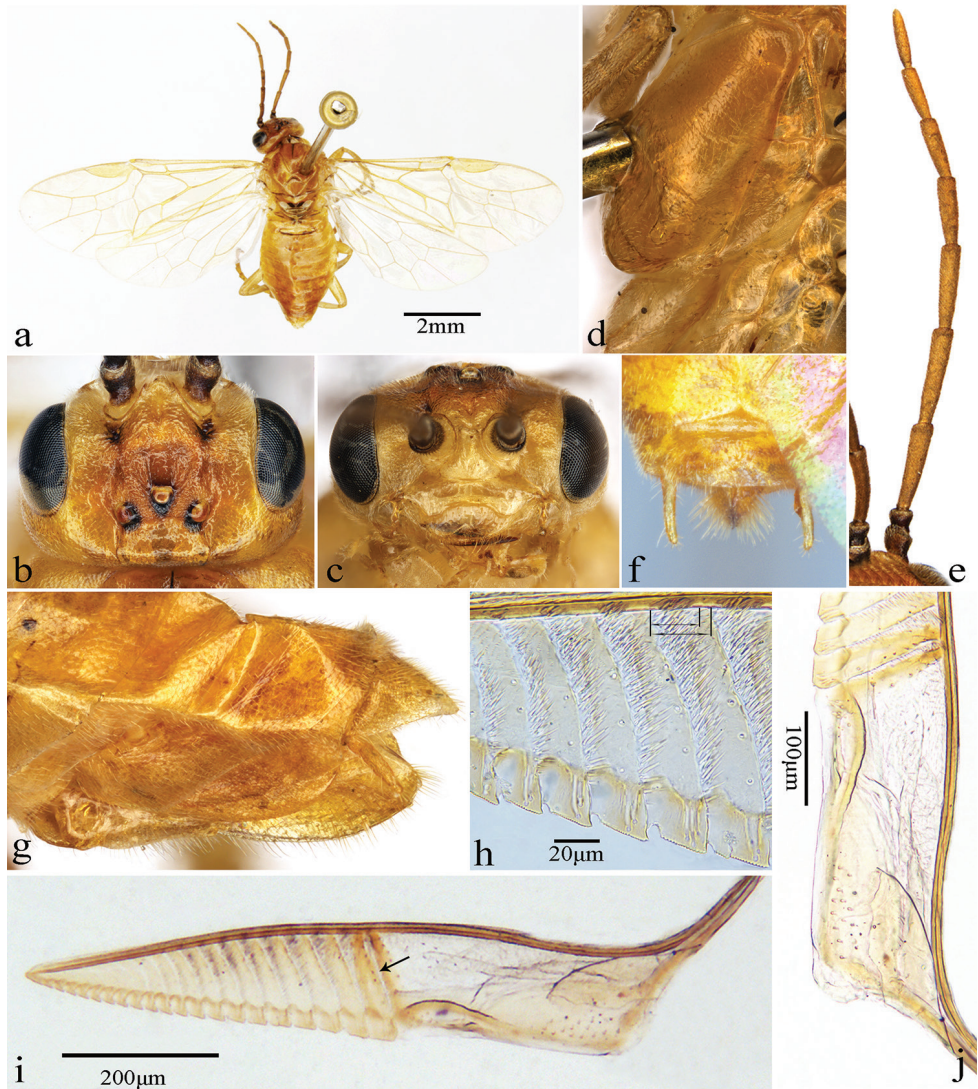


Figure 2. *Fagineura xanthosoma* sp. n., female, paratype. **a** Dorsal view **b** head, dorsal view **c** head, anterior view **d** mesopleuron and metapleuron **e** antenna, lateral view **f** ovipositor sheath, dorsal view **g** ovipositor sheath, lateral view **h** middle serrulae; the short double arrow denotes the longest setae band, the long double arrow denotes the length of the annulus **i** lancet; the arrow denotes the annular suture **j** tangium.

Mountain, 1000 to 1300 m, 24 April 2004, leg. Meicai Wei; 1 ♀, **China**, Hunan Province, Yongzhou City, Yangming Mountain, 1000 to 1300 m, 24 April 2004, leg. Wei Xiao.

Diagnosis. Body pale yellow to pale yellowish-brown; stigma and most parts of veins pale yellow (Fig. 2a); frons slightly shiny, with some hair warts and wrinkles, punctures weak and very sparse; malar space $0.8 \times$ as long as diameter of median ocellus; interocellar furrow broad and very shallow, postocellar furrow broad and slightly shallow; postocellar area convex, without mesosulcus, $2.8 \times$ as wide as long

(Fig. 2b–c); relative length of antennomere 3 : antennomere 4 : antennomere 5 = 1.0 : 1.2 : 1.0 (Fig. 2e); vein M about as long as vein R+M; forewings with cross-vein cu-a joining cell 1M at basal 0.6, cell 2Rs 1.4 × as long as wide, petiole of hind anal cell 1.3 × as long as cu-a (Fig. 2a); lancet with 21 serrulae (Fig. 2i); each middle serrula always with 14–17 distal teeth (Fig. 2h); annular suture 1 straight but oblique, sutures 1–13 with setae bands, longest setae band approx. 0.9 length of annulus; tangium 5.5 × as long as annulus 1, radix 0.6 × as long as lamnium (Fig. 2i, 2j).

Description. Holotype, female. Body length approximately 7.0 mm (Fig. 2a).

Color. Body pale yellow to pale yellowish-brown. Lateral fovea, around ocelli, dorsal side of scape and pedicel, anterior edge and medial spot of tergum 1 black; cenchrus yellowish-white. Wings hyaline, stigma and most parts of veins pale yellow.

Head. Inner margins of eyes slightly convergent downward in frontal view, distance between eyes 2.4 × as long as height of eye (Fig. 2c). Base of labrum elevated, and apex rounded; base of clypeus elevated, anterior margin of clypeus incised to 0.3 × length of clypeus, lateral corners rounded; labrum and clypeus smooth and shiny, with few faint setigerous punctures, without microsculpture. Malar space 0.8 × as long as diameter of median ocellus (Fig. 2c). Middle fovea long, groove-like, deep. Frons slightly elevated, slightly shiny, with some hair warts and wrinkles, punctures weak and very sparse; anterior wall elevated and curved, notched medially, lateral walls distinct, but low and blunt. Interocellar furrow broad and very shallow, postocellar furrow broad and shallow; circumocellar furrow indistinct; POL : OOL : OCL = 0.9 : 1.0 : 0.7 (Fig. 2b). Vertex and postocellar area shiny, punctures faint and sparse, microsculpture indistinct; postocellar area convex, without mesosulcus, 2.8 × as wide as long, lateral furrows short, slightly broad and shallow; in dorsal view, inner margins of eyes subparallel (Fig. 2b). Antenna filiform, shorter than thorax and abdomen together, antennomere 3 slightly compressed; antennomere 2 1.3 × as wide as long, relative length of antennomere 3 : antennomere 4 : antennomere 5 = 1.0 : 1.2 : 1.0 (Fig. 2e).

Thorax. Mesonotum slightly shiny, with minute and dense punctures, microsculpture indistinct; median mesoscutal groove shallow and narrow; mesoscutellum shiny, with weak and slightly sparse punctures, and flat, middle ridge indistinct, 0.8 × as long as wide; mesoscutellar appendage shiny, with faint and sparse punctures, without microsculpture, approx. 0.4 × as long as scutellum, middle ridge faint. Distance between cenchri as long as breadth of cenchrus. Mesepisternum shiny, setigerous punctures weak and slightly dense, microsculpture indistinct; mesepimeron shiny, with few faint punctures, with some microsculpture on margins, posterior part of katepimeron extensively covered with setae; metapleuron shiny and smooth, punctures and microsculpture indistinct (Fig. 2d). Vein Sc little basad of origin of vein M from R, vein M about as long as vein R+M; forewings with cross-vein cu-a joining cell 1M at basal 0.6, cell 2Rs 1.4 × as long as wide, petiole of anal cell of hindwing 1.3 × as long as cu-a (Fig. 2a).

Abdomen. All abdominal terga slightly shiny, with faint and sparse setigerous punctures, microsculpture fine and very dense. Ovipositor sheath shiny, punctures laterally on valvula 3 weak and sparse, microsculpture indistinct; ovipositor sheath 1.9

\times as long as metatarsomere 1 and $1.2 \times$ as long as front tibia, valvula 3 $1.3 \times$ as long as valvifer 2; in lateral view, sheath tapering toward apex (Fig. 2g); in dorsal view, apex of cercus protruding beyond valvula 3, angle between most lateral setae of valvula 3 about 85° (Fig. 2f). Lancet with 21 serrulae (Fig. 2i); each middle serrula always with 14–17 distal teeth (Fig. 2h); annular suture 1 straight but oblique, sutures 1–13 with setae bands, longest setae band approx. $0.9 \times$ length of annulus; cypsella of serrulae 1–2 nearly absent, cypsella of serrulae 3–19 very short and deep; tangium $5.5 \times$ as long as annulus 1, with many campaniform sensilla (Fig. 2j), radix $0.6 \times$ as long as lamnium (Fig. 2i).

Legs. Protarsomere 1 slightly shorter than combined length of tarsomeres 2–4; inner apical spur of hind tibia $0.4 \times$ as long as metatarsomere 1, metatarsomere 1 $0.7 \times$ as long as combined length of metatarsomeres 2–5; tarsal claw with inner tooth slightly shorter than outer tooth.

Male. Unknown.

Distribution. China (Hubei, Hunan).

Variation. Body length 6.0–8.0mm; scape and pedicel partly to entirely black; around ocelli more or less black; vein Sc a little basad or interstitial with origin of vein M from R, and vein M as long as or slightly shorter than vein R+M; petiole of anal cell of hindwing 1.2 – $1.6 \times$ as long as cu-a; in dorsal view, apex of cercus protruding far as or beyond valvula 3.

Remarks. The new species is similar to *F. quercivora* Togashi, 2006, but can be distinguished from the latter by the following characters: mesepisternum entirely pale yellowish-brown; all coxae and hind tibia pale yellowish; terga 3–10 entirely pale yellowish-brown; ovipositor sheath yellow; malar space $0.8 \times$ as long as diameter of median ocellus; petiole of anal cell of hindwing longer than cu-a; tarsal claw with inner tooth shorter than outer tooth; lancet with 21 serrulae.

Etymology. The specific name is derived from the body color of adults.

Phylogenetic analyses

A Kimura 2-parameter model of COI and NaK distances within *Fagineura* species is shown in Table 2, and the mean distances within *Nematus*, *Fagineura*, *Pristiphora*, *Euura*, *Mesoneura* respectively and distances between these genera are shown in Table 3. The best-fitting model for the two-gene alignment was GTR+I+G (Nei and Kumar 2000). In MrBayes, default priors were used, and two parallel runs having four incrementally heated chains for 1.5 million generations were made, while sampling trees from the current cold chain every 1000 generations. 375 trees sampled were discarded prior to reaching chain stationarity as a burn-in from both runs, and the remaining 1126 trees were used to calculate a 50% majority consensus rule tree, showing all groupings with posterior probability more than 0.5 (Fig. 3).

The two new species and *Fagineura crenativora* are separated by an adequate distance (Tables 2, 3), and all three species form a monophyletic group (Fig. 3). The K2P

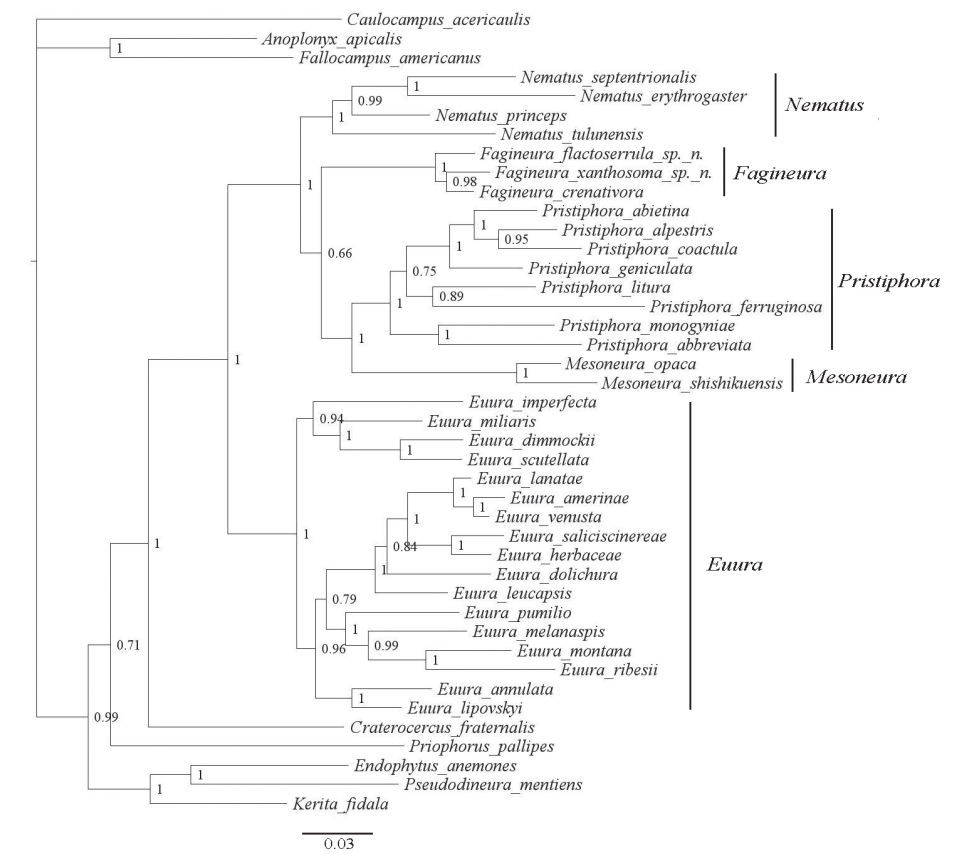


Figure 3. Phylogenetic tree of three *Fagineura* species and other representative species of the Nematinae based on Bayesian phylogenetic analysis of COI and NaK sequences. Numbers at right of nodes show Bayesian posterior probabilities (PP). The scale bar shows the number of estimated substitutions per nucleotide position.

Table 2. Kimura 2-parameter model distances among *Fagineura* species based on COI (below) and NaK (above) sequences.

Species	Distance between species		
	<i>F. flactoserrula</i>	<i>F. xanthosoma</i>	<i>F. crenativora</i>
<i>Fagineura flactoserrula</i>		0.005	0.005
<i>Fagineura xanthosoma</i>	0.067		0.004
<i>Fagineura crenativora</i>	0.052	0.050	

Table 3. Mean Kimura 2-parameter model distances for COI (below) and NaK (above) within and among large genera of the Nematinae.

Genus	Distance within genus		Distance between genera				
	COI	NaK	<i>Nematus</i>	<i>Fagineura</i>	<i>Pristiphora</i>	<i>Euura</i>	<i>Mesoneura</i>
<i>Nematus</i>	0.140	0.052		0.089	0.090	0.110	0.108
<i>Fagineura</i>	0.056	0.005	0.123		0.091	0.119	0.109
<i>Pristiphora</i>	0.139	0.042	0.148	0.128		0.129	0.106
<i>Euura</i>	0.111	0.052	0.135	0.121	0.148		0.154
<i>Mesoneura</i>	0.062	0.026	0.134	0.116	0.131	0.129	

distance based on COI and NaK between *F. flactoserrula* and *F. xanthosoma* are 6.7% and 0.5%, between *F. flactoserrula* and *F. crenativora* 5.2% and 0.5%, and between *F. xanthosoma* and *F. crenativora* 5.0% and 0.4%, respectively. The distance, based on COI and NaK, is 11.6% between *Fagineura* and *Mesoneura* and 8.9% between *Fagineura* and *Nematus*. These results are consistent with the morphological taxonomy described above. Unfortunately, sequences of *F. quercivora* are not available in GenBank, and we did not have any specimens of this species available. However, the two new species can be easily separated from *F. quercivora* by morphological characters.

Discussion

In this paper, two new species of *Fagineura* are described and illustrated. Compared to the generic characters of *Fagineura* proposed by Shinohara et al. (2000) and Prous et al. (2014), there are two differences in *F. flactoserrula*, including that the tangium lacks or has only one campaniform sensillum, and that the mesothoracic katepimeron is covered with only few setae. However, the generic characterisation in the earlier publications was based only on the two species known at that time, so that the previous definition of the genus apparently does not encompass the full range of interspecific variability. The phylogenetic analyses support placement of the two new species in *Fagineura*, and that they are different from *F. crenativora*. The new species are also different from *F. quercivora* based on morphological characters.

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A review of *Timandra* Duponchel, 1829 from China, with description of seven new species (Lepidoptera, Geometridae)

Le Cui^{1,2}, Dayong Xue¹, Nan Jiang¹

1 Key Laboratory of Zoological Systematics and Evolution, Institute of Zoology, Chinese Academy of Sciences, Beijing 100101, China **2** University of Chinese Academy of Sciences, Shijingshan District, Beijing 100049, China

Corresponding author: Nan Jiang (jiangn@ioz.ac.cn)

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Abstract

The Chinese species of the genus *Timandra* Duponchel, 1829 are reviewed: 12 known species are reported. Seven new species are described from China, increasing the total number of *Timandra* species to 28: *T. distorta* sp. n., *T. adunca* sp. n., *T. quadrata* sp. n., *T. accumulata* sp. n., *T. viminea* sp. n., *T. robusta* sp. n. and *T. stueningi* sp. n. Diagnoses for all 19 Chinese species are provided, with illustrations of external features and genitalia.

Keywords

Morphology, Sterrhinae, taxonomy, Timandrini

Introduction

The genus *Timandra* was originally established by Duponchel (1829) based on *Timandra griseata* Petersen, 1902, and he cited this species as *amataria* Linnaeus, 1761 due to a misidentification (Fletcher 1979). *Timandra* is the type genus of the tribe Timandrini. Its constituent species are distributed mainly in Asia, although the ranges of some extend to Europe and North America (Prout 1912–1916; Parsons et al. 1999; Hausmann 2004). The tribe Timandrini contains four genera: *Timandra*, *Synegiodes* Swinhoe, 1892, *Traminda* Saalmüller, 1891, and *Haematopsis* Hübner, 1823. The general char-

acters of *Timandrina* are as follows: the antennae of the male are bipectinate; the hind tibia of the male has no hair pencil; only one areole is present on the forewing, the veins R_{2+4} are always arising from the apex of the areole; the upper side of wings usually shows oblique transverse lines (except *Synegiodes*); in the male genitalia, the socii are often well developed, the valva is elongate and sometimes complex or bifurcate; in the female genitalia, the signum consists of a longitudinal ridge (Holloway 1997; Hausmann 2004; Sihvonen and Kaila 2004). However, there are no unique synapomorphies for *Timandrina* (Sihvonen and Kaila 2004), and the delimitation of tribe still needs further study.

Species belonging to *Timandra* are usually easy to be distinguished from other geometrids, although the Western Palaearctic *Scopula imitaria* (Hübner, 1799) and some American species of *Arcobara* Walker, 1863 have similar pattern and wing shape. Prout (1913) briefly discussed the nomenclature of this genus and listed five species with concise descriptions. Later, he (Prout 1935) recorded ten *Timandra* species under the genus name *Calothysanis* Hübner, 1823 (an older name, which is currently treated as a subgenus of the genus *Scopula* Schrank, 1802; cf. Fletcher 1978, Hausmann 2004) and divided them into two sections according to the characters of the uncus. Kaila and Albrecht (1994) reviewed the European *Timandra griseata* group, and established three new combinations. Holloway (1997) recorded one species from Borneo, and summarized the characters of *Timandra* in detail. Sihvonen (2001) illustrated the everted vesicae of the male genitalia of *T. griseata* and *T. comae* and supported the conclusion of Kaila and Albrecht (1994) to treat them as valid species. Hausmann (2004) recorded three species from Europe with detailed descriptions and photos of the adults and the genitalia. Öunap et al. (2005) published a molecular phylogenetic study, which separates *T. griseata* and *T. comae* into different clades.

Twenty-one species have hitherto been recognized in *Timandra* (Parsons et al. 1999; Scoble and Hausmann 2007), including 12 species recorded in China (Prout 1912–1916, 1934–1939, 1920–1941; Chu and Xue 1988, 1992; Xue 1992a, 1992b; Wang 1997; Han and Xue 2002; Xue et al. 2002). In the course of an inventory of the Sterrhinae of China (Cui et al. 2018a, 2018b; Xue et al. 2018), it became apparent that several new species of *Timandra* need to be described.

The purpose of this paper is to provide a survey of Chinese *Timandra* species, to describe the seven new species, and to provide diagnostic characters and illustrations of external features and genitalia of all Chinese species.

Materials and methods

Specimens of *Timandra* are deposited in the following collections:

BRCAS	Biodiversity Research Center, Academia Sinica, Taiwan
IZBE	Zoological-Botanical Institute of the Academy of Sciences, Tartu, Estonia
IZCAS	Institute of Zoology, Chinese Academy of Sciences, Beijing, China
NEFU	Northeast Forestry University, Harbin, China
NHM	Natural History Museum, London, UK

NHRS	Naturhistoriska Riksmuseet, Stockholm, Sweden
NKU	Nankai University, Tianjing, China
TFRI	Taiwan Forestry Research Institute, Taipei
ZFMK	Zoologisches Forschungsmuseum Alexander Koenig, Bonn, Germany

Terminology for wing venation follows the Comstock-Needham system (Comstock 1918) as adopted for Geometridae by Scoble (1992) and Hausmann (2001); terminology for genitalia follows Pierce (1914, reprint 1976), Klots (1970), Nichols (1989), Kaila and Albrecht (1994), and Hausmann (2004). Photographs of the moths were taken with digital cameras. Composite images were generated using Auto-Montage software v. 5.03.0061 (Synoptics Ltd). The plates were compiled using Adobe Photoshop v. 7.0. Ink (Adobe Systems Software Ireland Ltd).

Systematics

Genus *Timandra* Duponchel, 1829

Timandra Duponchel, 1829: 105. Type species: *Timandra griseata* Petersen, 1902.

Bradyepetes Stephens, 1829: 44. Type species: *Timandra griseata* Petersen, 1902 [junior objective synonym of *Timandra* Duponchel].

Bradypetes Agassiz, 1847: 52 [emendation of *Bradyepetes* Stephens].

Generic characters. *Head.* Male antennae bipectinate, pectination covered with ciliae, usually black on basal part; female antennae filiform. Labial palpi with last segment narrow. Hind tibia in male not dilated, with two pairs of spurs, sometimes a black spot present at apex of one spur in each pair. *Venation.* Forewing with one areole; R_1 arising distally or directly from apex of areole; R_5 sometimes stalked with R_{2-4} , sometimes not. Hindwing with R_s and M_1 separate or shortly stalked, M_3 and CuA_1 separate. Forewing with acute apex, sometimes protruding outside, outer margin nearly straight or slightly arched; hindwing with outer margin forming a small protrusion on vein M_3 . Forewing with medial line oblique, arising from apex or subapex; postmedial line narrow, usually overlapping with medial line near apex. Hindwing with medial line straight. Postmedial line and discal spot often more distinct on underside than those on upperside.

Male genitalia. Uncus often short digitiform, or slightly raised, sometimes dilated at tip. Socii usually well developed, sometimes absent. Valva with sclerotized structures and usually bifurcate; costa often sclerotized with a process; a short or tuberculate process usually present at base of valvula; a digitate arm usually extending from cleft between valvula and sacculus; sacculus often short, sometimes long and narrow, sometimes asymmetric between right and left valva. Juxta usually broad at base. Saccus often broad, sometimes concave. Aedeagus straight or curved; vesica with or without cornutus.

Female genitalia. Seventh sternite usually strongly sclerotized and bifurcate on posterior margin, sometimes membranous. Papillae anales usually stout and short. Sterigma sometimes developed. Colliculum present. Ductus seminalis usually arising from poste-

rior part of ductus bursae or apex of appendix bursae. Ductus bursae usually sclerotized on posterior part. Corpus bursae usually long and oval, membranous; signum with a longitudinal sclerite inside a slightly sclerotized plate, a pouch present on anterior part.

Diagnosis. *Timandra* can be distinguished from other genera within Timandriini in the following external characters: the vein $Sc+R_1$ of the hindwing is less strongly anastomosing with the cell in *Timandra* than in *Haematopsis* (Prout 1931); the outer margin of the forewing below the apex often has an incision in *Traminda*, while it is straight in *Timandra*; the discal spot is reddish-brown or brown in *Timandra*, but consists of a black circle with a white center in *Synegiodes*. In the genitalia, *Timandra* can be easily distinguished by the combination of the following characters: the valva of the male genitalia is complex and often divided into two parts, with a slender digitiform process usually arises from the cleft between the valvula and the sacculus; the seventh sternite of the female is usually strongly sclerotized and bifurcated on the posterior margin.

Distribution. Asia, Europe, and North America.

Host-plant. Larvae have been recorded on Polygonaceae only (Holloway 1997; Hausmann 2004).

Remarks. We found that the shape of the frons is variable in Chinese species of *Timandra*: slightly protruded in *T. oligoscia* Prout, 1918, *T. quadrata* sp. n., *T. robusta* sp. n., *T. dichela* (Prout, 1935), *T. griseata* Petersen, 1902, *T. extremaria* Walker, 1861, and *T. recompta* (Prout, 1930) (Fig. 38); fully protruded in *T. paralias* (Prout, 1935) and *T. distorta* sp. n. (Fig. 39); forming a rounded protrusion in *T. accumulata* sp. n. (Fig. 40), *T. apicirosea* (Prout, 1935), *T. ruptilinea* Warren, 1897, and *T. comptaria* Walker, 1863; with a sharp protrusion in *T. adunca* sp. n., *T. convectaria* Walker, 1861 (Fig. 41), and *T. correspondens* Hampson, 1895; protruded with an obtuse protrusion on the ventral margin in *T. viminea* sp. n. (Fig. 42); not protruding in *T. stueningi* sp. n.

The seventh sternite of the female is often not separated from the female genitalia, except in *T. griseata*, *T. convectaria* Walker, 1861, *T. viminea*, and *T. ruptilinea* Warren, 1897 in the present study (Figs 61, 65, 70, 72).

A male specimen from Hong Kong has a slightly different wing pattern from the other recognized species of *Timandra*, and may be a new species (Roger Kendrick pers. comm.). However, as only one specimen has been found, more specimens need to be collected and studied to allow for a full description.

Timandra griseata Petersen, 1902

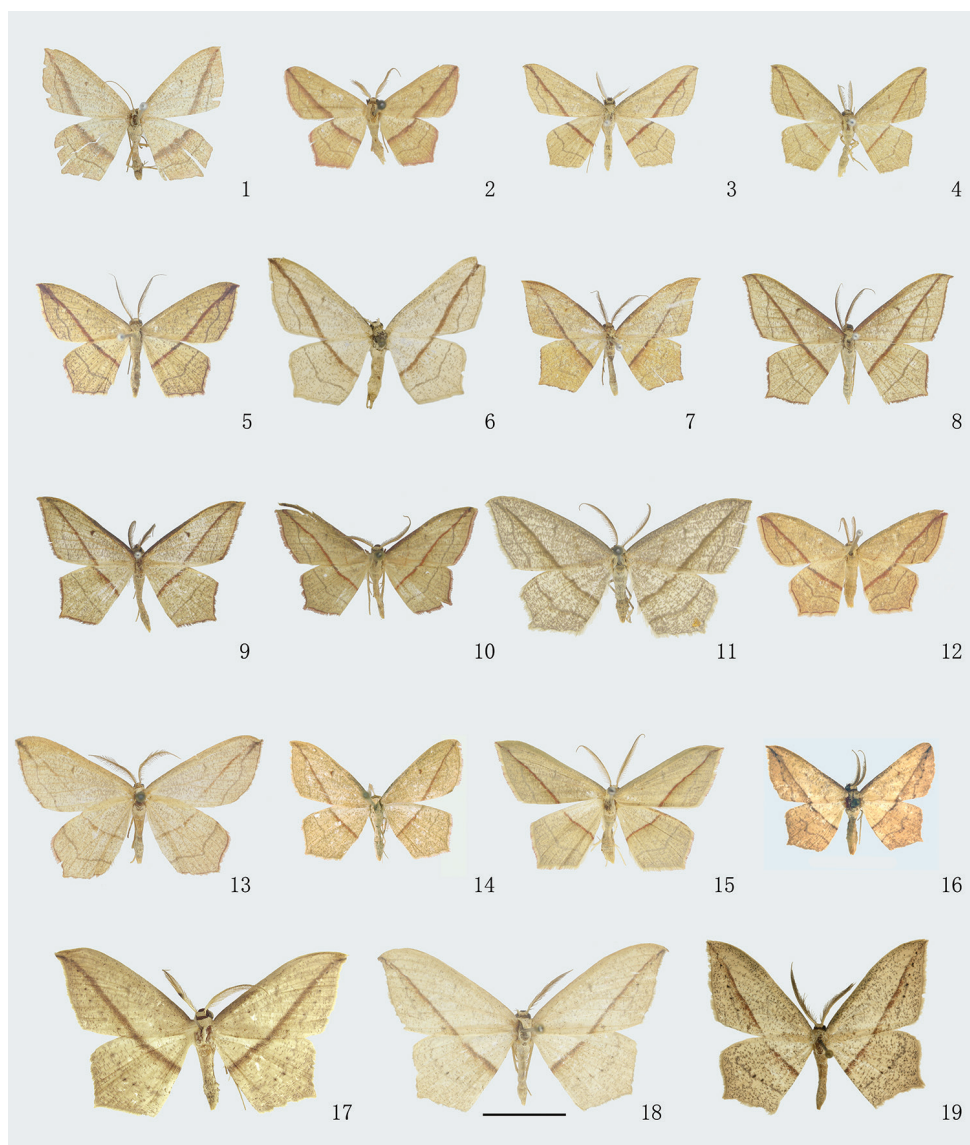
Figs 1, 61

Timandra amata var. *griseata* Petersen, 1902: 239. Lectotype ♂, Estonia (IZBE).

Timandra serpentata ab. *griseata*: Prout 1913: 98.

Timandra griseata: Hausmann 2004: 390.

Diagnosis. This species is very similar to *T. comae* Schmidt, 1931, but the combination of the following characters can distinguish them: the ground colour of the forewing is whitish in *T. griseata*, but often yellowish in *T. comae*; the surface of the wings



Figures 1–19. Adults of *Timandra*. **1** *T. griseata*, female, Xinjiang **2** *T. recompta*, male, Beijing **3** *T. apicirosea*, male, Sichuan **4** *T. distorta* sp. n., holotype, male, Tibet **5** *T. dichela*, male, Hubei **6** *T. synthaca*, holotype, male, Taiwan **7** *T. convectaria*, male, Guangxi **8** *T. correspondens*, male, Tibet **9** *T. adunca* sp. n., holotype, male, Yunnan **10** *T. quadrata* sp. n., holotype, male, Hubei **11** *T. accumulata* sp. n., holotype, male, Yunnan **12** *T. comptaria*, male, Zhejiang **13** *T. paralias*, male, Hebei **14** *T. viminea* sp. n., holotype, male, Yunnan **15** *T. oligoscia*, male, Yunnan **16** *T. ruptilinea*, male, Guangdong **17** *T. extremaria*, male, Gansu **18** *T. robusta* sp. n., holotype, male, Yunnan **19** *T. stueningi* sp. n., holotype, male, Taiwan. Scale bar: 1 cm.

is densely speckled with grey scales in *T. griseata*, but it is covered with brownish-grey speckles in *T. comae*; the average wingspan is larger and sexual size dimorphism is more accentuated in *T. griseata*. The appendix of the sacculus of the male genitalia is on aver-

age slightly broader at base in *T. griseata* than that in *T. comae*. In the female genitalia, the ductus bursae is stouter at the anterior half in *T. griseata*; the posterior appendix bursae of the ductus bursae arises at a bigger angle to the corpus bursae in *T. griseata* (Kaila and Albrecht 1994; Hausmann 2004; Öunap et al. 2005).

Material examined. CHINA: Xinjiang (IZCAS): 1♀, Gongliu, Kuerdening, 1100 m, 26.VII.2017, coll. Cheng Rui.

Distribution. China (Xinjiang), Europe.

Remarks. This species is newly added to the fauna of China.

Timandra reompta (Prout, 1930)

Calothyranis amata reompta Prout, 1930: 297. Holotype ♂, Russia: Ussuri [Ussuri region], Chabarovsk, Ussuri railway (NHM).

Timandra amataria myokosana Bryk, 1948: 159, pl. 7, fig. 9. Holotype ♂, Korea: Myokosan (NHRS).

Timandra reompta: Kaila and Albrecht 1994: 461.

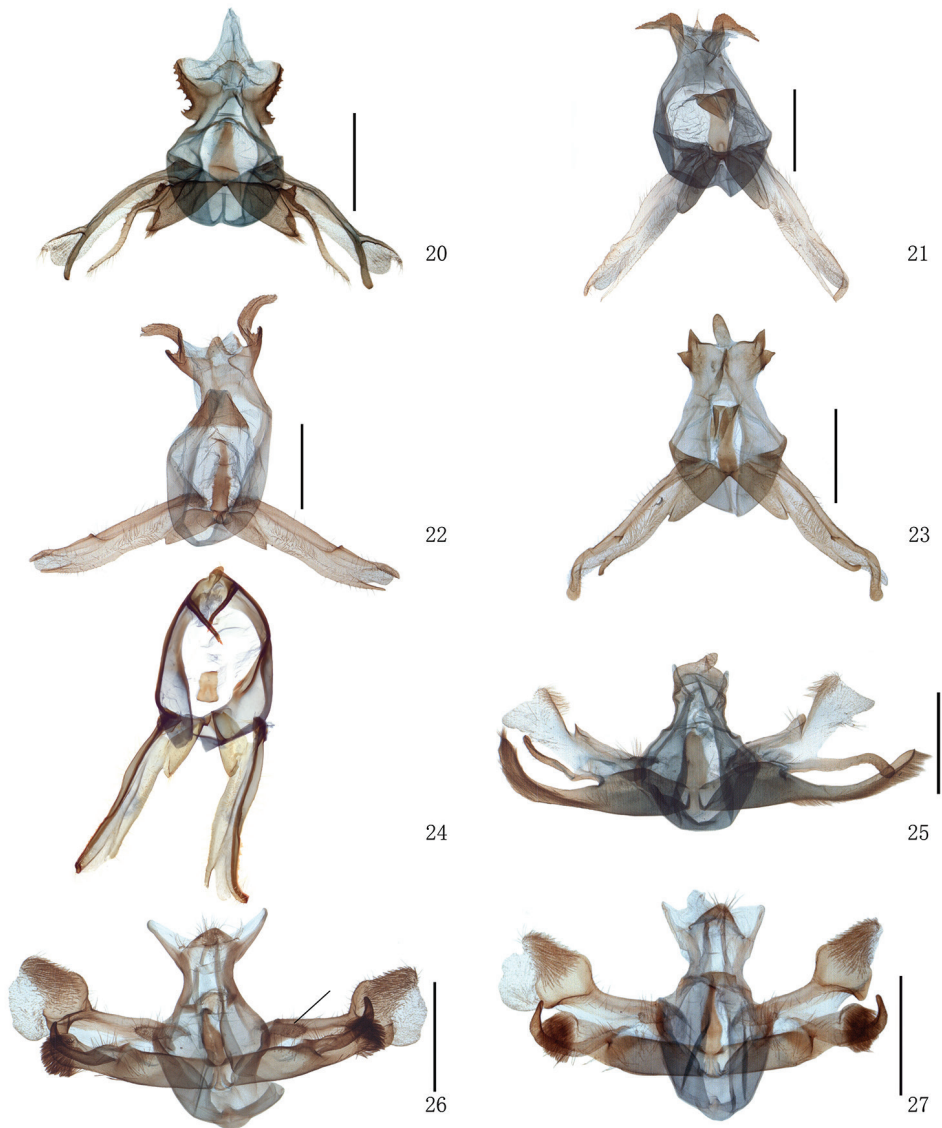
Remarks. At present, this species comprises three subspecies; other two subspecies are distributed in Japan and on Kurile Islands (Parsons et al. 1999).

Timandra reompta reompta (Prout, 1930)

Figs 2, 20, 38, 43, 62

Diagnosis. This species can be distinguished from its congeners by the following characters: the frons is slightly protruded; the pinkish-red shadow is present along the medial line and on the outer margin of both wings; in the male genitalia, the socii have a strongly serrate margin; the valvula has a narrow digitiform process subapically at the costa; the sacculus is short and with a pointed apex; the cornutus is short and stout with tiny spines. The female genitalia are similar to those of *T. griseata*, but the posterior margin of the seventh sternite is concave centrally.

Material examined. CHINA: Heilongjiang (IZCAS): 3♀, Yichun, 15.IV.1957, 3.IX.1970; 16♂, Yichun, Dailing, 390 m, 24.VI.1957, 2.VIII–5.IX.1957, 24.VII.1958, 6.VII–2.VIII.1959, 8.VI.1962, coll. Bai Jiuwei et al.; 3♂1♀, Yichun, Wuyiling, 30–31.VIII.1970; 1♀, Yabuli, 29.VII.1939; 1♀, Mishan, Errenban, 11.VIII.1970. Liaoning (IZCAS): 1♂, Xinjin, 1954, coll. Ou Bingrong; 1♂, Anshan, Qian Shan, 30.VII–4.VIII.2008, coll. Han Huilin et al. (presented by Northeast Forestry University); 1♂, Dalian, 8–11.IX.2008, coll. Han Huilin et al. (presented by Northeast Forestry University); 5♂4♀, Faku, Chenwushitun; Wangyeling; Hongshadi; 23.VII–6.VIII.2006, coll. Wang Yiping (loaned from by insect specimen room of Nankai University); 6♂, Panjin, Rongxing, Youyan'gou, 18.IX.2017, coll. Wu Chunguang; 1♂, Rongxing, Xiaozhuangzi, 20.IX.2017, coll. Wu Chunguang. Inner Mongolia (IZCAS): 1♂, Yakeshi linqu, 20.VI.1983; 1♂, Yakeshi, Wuerhanqi, 30.VIII.1983; 1♂, Elunchunqi,



Figures 20–27. Male genitalia of *Timandra*. **20** *T. recompta*, Heilongjiang **21** *T. apicirosea*, Sichuan **22** *T. distorta* sp. n., holotype, Tibet **23** *T. dichela*, Hubei **24** *T. synthaca*, male, Taiwan (without scale) **25** *T. convectaria*, Sichuan **26** *T. correspondens*, black bar shows the tuberculate process at the base of the valvula, Tibet **27** *T. adunca* sp. n., holotype, Guangxi. Scale bar: 1 mm.

Dayangshu, 370 m, 6.VII.1985, coll. Xue Dayong; 4♂1♀, Humeng, Arongqi, 23–25. VIII.1986, coll. Qi Shaofu et al.; 1♂, Zhemeng, Kulunqi, 20.VIII.1987, coll. Gong Bingwen. **Beijing** (IZCAS): 2♂, Beiping, 11.VII.1949, 8.VIII.1949; 11♂2♀, Xijiao Park, 6.V.1951, 10, 26–27.VIII.1951, 1–9.IX.1952, coll. Zhang Yiran et al.; 1♂, Qinghe, 30.VIII.1957, coll. Mao Jinlong; 7♂2♀, Sanpu, 23.VII–14.IX.1964, coll. Liao

Subai et al.; 1♀, Mentougou, Liyuanling, 1100 m, 16.IX.2001, coll. Xue Dayong; 1♂, Chaoyang District, Institute of Zoology, Chinese Academy of Sciences, 24.VIII.2010, coll. Qi Feng; 3♂1♀, Miyun, 12.VII–11.IX.2010; 1♂, Changping, Liucun, Wangjiayuan, 160 m, 8.VIII.2008, coll. Wu Yupeng; 2♀, Changping, Baiyangcheng, 213 m, 15.VIII.2013, coll. Cui Le. **Hebei** (IZCAS): 1♀, Weixian, Xiheyang, 9.IX.1964, coll. Han Yinheng; 1♀, Chicheng, Longmensuo, Liuzhuanzi, 10–11.VIII.2006, coll. Yang Chao. **Shandong** (IZCAS): 1♀, Lao Shan, 800 m; 5♂, Qihe, 13.VIII.1969. **Henan** (IZCAS): 6♂1♀, Xinxiang, 22.IV–14.IX.1973; 2♂, Xinyang, 26.VIII.1981, 26.VIII.1982; 1♂, Xinyang, Wuxingxiang, 230 m, 18.VII.2002, coll. Han Hongxiang; 1♂, Xinyang, Jigong Shan, 250 m, 20–21.VII.2002, coll. Han Hongxiang; 1♂, Xixia, Taiping, 834 m, 5–6.VIII.2013, coll. Jiang Nan et al. **Xinjiang** (IZCAS): 1♂, Zhaosu, Alasan, 2400 m, 24.VII.1978, coll. Han Yinheng; 1♀, Akesu, 1180 m, 18.VI.1978, coll. Han Yinheng; 3♂, Xinyuan, Yeguolin, 1280 m, 23–25.VII.2017, coll. Cheng Rui. **Shanghai** (IZCAS): 2♂1♀, 21.VI.1930, 19.VIII.1935, 17.IX.1935, coll. O. Piel. **Zhejiang** (IZCAS): 1♀, Wenzhou, 16.IX.1996, coll. Ding Jianqin. **Hubei** (IZCAS): 2♂1♀, Jinzhou, VII–VIII.1960; 1♀, Luotian, Qingtaiguan, 560 m, 1–4.VII.2014, coll. Jiang Nan. **Jiangxi** (IZCAS): 1♂, Guling, 10.VIII.1935, coll. O. Piel; 1♂, Wannian, X.1979. **Hunan** (IZCAS): 1♂, Hengyang, 24.VI.1981, coll. Li Jutao. **Yunnan** (IZCAS): 1♀, Jinping, Hetouzhai, 1700 m, 14.V.1956, coll. Huang Keren.

Distribution. China (Heilongjiang, Jilin, Liaoning, Inner Mongolia, Beijing, Hebei, Shandong, Henan, Xinjiang, Shanghai, Zhejiang, Hubei, Jiangxi, Hunan, Yunnan), Russia (Ussuri), Korean Peninsula.

Timandra apicirosea (Prout, 1935)

Figs 3, 21, 44, 63

Calothysanis apicirosea Prout, 1935: 28, pl. 4: d. Holotype, Japan: Takao-San, near Tokyo (NHM).

Timandra apicirosea: Inoue 1977: 240.

Diagnosis. This species is very similar to *T. distorta* based on the characters of the adult and the male genitalia. However, it can be distinguished from *T. distorta* by the combination of the following characters: the frons is deep reddish-brown in *T. apicirosea* but yellowish-brown without reddish pigmentation in *T. distorta*; in the male genitalia, the uncus is smaller in *T. apicirosea* than in *T. distorta*; the socii form a right angle and are without process at the base in *T. apicirosea*, while these are weakly curved and with a triangular process at the base in *T. distorta*; the processes on the dorsal and the ventral margin of the valvula are obviously longer in *T. apicirosea* than in *T. distorta*; the juxta is broader in *T. apicirosea* than in *T. distorta*. The female genitalia are similar to those of *T. dichela* in having a slender seventh sternite, but the posterior bifurcate parts are more extended outwards in *T. apicirosea*; the ductus bursae is shorter in *T. apicirosea* than in *T. dichela*; the sclerotized part of the ductus bursae is smaller in *T. apicirosea* than that in *T. dichela*.

Material examined. CHINA: Hubei (IZCAS): 1♂, Yien, Changtanhe, Lianghekou, 949 m, 13–14.V.2017, coll. Li Henan. **Fujian** (IZCAS): 1♂, Shaxian, 25.VIII.1979, coll. Lin Naiquan; 1♀, Wuyi Shan, Sangang, 704 m, 21.X.2005, coll. Han Hongxiang; 1♂, Wuyi Shan, Taoyuanyu, 460 m, 24.X.2005, coll. Yang Chao. **Guangxi** (IZCAS): 1♀, Jinxiu, Luoxiang, 200 m, 15.V.1999, coll. Han Hongxiang; 1♀, Jinxiu, Zhong Gonglu, 1000 m, 10.V.1999, coll. Han Hongxiang; 2♀, Mao'er Shan, Gaozhai, 448 m, 13–15.VIII.2012, coll. Yang Chao et al.; 1♂, Mao'er Shan, Jiuniutang, 1146 m, 16.VIII.2012, coll. Yang Chao; 1♀, Huanjiang, Yangmei'ao, 1189 m, 18–22.VII.2015, coll. Li Xinxin. **Sichuan** (IZCAS): 1♀, Guanxian, Qingcheng Shan, 700–1600 m, 4.VI.1979, coll. Shang Jinwen; 2♂, Mianzhu, Jiulong Shan, Shizipo, 810 m, 29–31.VII.2016, coll. Cui Le; 1♂, Wenchuan, Sanjiang Fengjingqu, 1349 m, 25.VIII.2013, coll. Cheng Rui; 1♂, Hongya, Wawu Shan, Jinhuaqiao, 1147 m, 12–14.VIII.2016, coll. Cui Le.

Distribution. China (Inner Mongolia, Gansu, Hubei, Jiangxi, Hunan, Fujian, Guangxi, Sichuan), Japan, Russia (Ussuri).

***Timandra distorta* sp. n.**

<http://zoobank.org/80704E88-40B0-4E5D-A001-7EB1243E9690>

Figs 4, 22, 39, 45

Description. *Head.* Antennae bipectinate in basal four-fifths in male, dorsal surface of shaft yellowish-brown, sometimes covered with brown scales, pectination covered with ciliae, basally black. Frons yellowish-brown with ventral side yellowish-white, slightly protruding (Fig. 39). Labial palpi yellowish-brown, reaching to tip of frons. Vertex pale yellowish-brown. *Thorax.* Patagia yellowish-brown. Tegulae and thorax pale yellowish-brown. Hind tibia with two pairs of spurs in male. Forewing length: male 12–15 mm. Forewing with apex pointed, slightly protruding; costa curved on terminal part; outer margin slightly protruding below vein M_3 . Apical angle of hindwing rounded, outer margin protruding on vein M_3 . Wing colour pale yellowish-brown, covered with blackish-brown spots especially on costal area of forewing. Forewing with discal spot reddish-brown and small; medial line reddish-brown, straight and narrow, arising from apex and extending to middle part of terminal margin; postmedial line overlapping with medial line near apex, separating from it on vein R_5 , slightly convex between veins M_3 and CuA_1 ; terminal line reddish-brown and very narrow. Fringes yellowish-brown, mixed with reddish-brown terminally. Hindwing with medial line reddish-brown, straight, narrow; postmedial line protruding between veins M_3 and CuA_1 ; terminal line and fringes similar to those of forewing. Underside densely covered with dark brown speckles; discal spot of forewing and postmedial lines of both wings darker than those of upperside.

Male genitalia. Uncus small and stout, rounded at apex. Socii thin and flat, curved, covered with small spurs on surface, extending beyond tip of uncus; a short and triangular process present at base of outer margin of both socii. Costa with a ridge

at approximately one-third from apex; valvula forming a narrow digitiform process both at apex of costa and on ventral margin, apical part of valvula between two processes membranous; sacculus short and stout, acute at tip. Juxta long, narrowing in terminal part. Aedeagus with basal half narrow; vesica partly sclerotized and crinkled.

Female genitalia. Unknown.

Diagnosis. The most discriminating character between *T. apicirosea* and *T. distorta* is the shape of the socii of the male genitalia. For more comparisons, see *T. apicirosea* above.

Type material. Holotype, ♂, **CHINA: Tibet** (IZCAS): 1♂, Mêdog, Yarang, 1091 m, 20–23.VIII.2006, coll. Lang Songyun. Paratype: **Tibet** (IZCAS): 1♂, Bomi, 2750 m, 26.VIII.1982, coll. Han Yinheng.

Distribution. China (Tibet).

Etymology. The species is named referring to the Latin *distortus*, which refers to the curved socii in the male genitalia.

Timandra dichela (Prout, 1935)

Figs 5, 23, 46, 64

Calothyssanis dichela Prout, 1935: 29, pl. 4: d. Syntypes ♂, Russia: S. Ussuri, Narva (NHM).

Timandra dichela: Inoue 1977: 240.

Diagnosis. This species is very similar to *T. apicirosea* and *T. distorta* in its external characters. The species can be distinguished by the following characters: the colour of the frons is deeper in *T. dichela* than that in *T. apicirosea*, and without reddish pigmentation in *T. dichela*. In the male genitalia, the uncus is longer in *T. dichela* than in *T. apicirosea* and *T. distorta*; the socii are composed of two short acute processes on both sides of the tegumen in *T. dichela*, while these are much longer and digitiform in *T. apicirosea* and *T. distorta*; the process on the dorsal margin of the valvula is much stouter in *T. dichela* in comparison with *T. apicirosea* and *T. distorta*. The diagnostic characters of the female genitalia are given under *T. apicirosea*.

Material examined. **RUSSIA** (NHM): 1♂, holotype, Narva, S Ussurigebie, 9.821, N Kardakoff, Joicey, Bequest, Brit. Mus. 1934-120. **CHINA: Henan** (IZCAS): 1♀, Xinyang, Jigong Shan, 250 m, 20–21.VII.2002, coll. Han Hongxiang. **Zhejiang** (IZCAS): 1♀, Yuyao, Siming Shan, 814 m, 31.VII–2.VIII.2016, coll. Li Xinxin; 1♂, Zhoushan, Putuo, Taohuodao, 40 m, 4.VIII.2016, coll. Li Xinxin. **Hubei** (IZCAS): 1♀, Shennongjia, Dajiuhu, 1800 m, 4.VIII.1981, coll. Han Yinheng; 1♂, Zigui, Maoping, 80 m, 27.IV.1994, coll. Yao Jian; 4♂1♀, Yingshan, Taohuachong, 590 m, 23–27.VI.2014, coll. Jiang Nan et al.; 4♂2♀, Yingshan, Wujia Shan, 860 m, 28–30.VI.2014, coll. Cui Le et al.; 1♂5♀, Luotian, Qingtaiguan, 560 m, 1–4.VII.2014, coll. Xue Dayong et al. **Jiangxi** (IZCAS): 1♂1♀, Jinggang Shan, Xiazhuang, 590 m, 5.VIII.2013, coll. Xue Dayong et al. **Hunan** (IZCAS): 1♂, Zhangjiajie, Wulingyuan, Wenfeng, 334 m, 11.V.2017, coll. Li Henan; 1♂, Yanling, Taoyuandong, 631 m, 4–8.

VII.2008, coll. Chen Fuqiang; 2♂, Zhangjiajie, Wulingyuan, 267 m, 13.VI.2015, coll. Zhao Kaidong; 1♂, Zhangjiajie, Wulingyuan, Wenfeng, 350 m, 17.IX.2015, coll. Zhao Kaidong; 4♂6♀, Heng Shan, 22, 24, 29, 30.VIII.1979, 1–2.IX.1979, coll. Zhang Baolin; 1♀, Changsha, 29.VII.1983, coll. Zhang; 1♂, Zhangjiajie, 8.X.1988, coll. Fang Chenglai. **Fujian** (IZCAS): 3♂2♀, Wuyi Shan, Sangang, 704 m, 17.VIII.1979, 30.VI.1982, 20.X.2005, 11–14.VIII.2009, coll. Song Shimei et al.; 1♂, Linxia, 17.X.1980, coll. Huang Shuishi. **Guangdong** (IZCAS): 3♂, Shixing, Chebal-ing, 330 m, 1–2.VIII.2013, coll. Yang Chao et al.; 1♂, Ruyuan, Nanling conservation area, 1020 m, 16–20.VII.2008, coll. Chen Fuqiang. **Sichuan** (IZCAS): 1♀, Emei Shan, Qingyinge, 800–1000 m, 21.VI.1957, coll. Zhu Fuxing. **Yunnan** (IZCAS): 1♂, Yanjin, Hongli hotel, 469 m, 17–19.VIII.2016, coll. Cui Le.

Distribution. China (Henan, Zhejiang, Hubei, Jiangxi, Hunan, Fujian, Taiwan, Hainan, Guangdong, Sichuan, Yunnan), SE Russia, Japan, Korean Peninsula, India.

Timandra synthaca (Prout, 1938)

Figs 6, 24, 47

Calothysanis synthaca Prout, 1938: 154, pl. 16: g. Holotype ♂, Formosa [China: Taiwan] (central): Kagi district (NHM).

Timandra synthaca: Inoue 1992: 122.

Diagnosis. This species is very similar to *T. apicirosea*. The following characters of the male genitalia distinguish it from *T. apicirosea*: the uncus is stouter; the socii are narrower and less strongly curved; the costa of the valva is more strongly sclerotized. The female genitalia of this species are unknown.

Material examined. **CHINA: Taiwan** (NHM): 1♂, holotype, Central Formosa, Kagi district, Rothschild Bequest, 1939-1; **Taiwan** (BRCAS): 1♂, Hualien Co., Xin-baiyang (site 1), 1734 m, 22–23.VII.2015, coll. S. Wu.

Distribution. China (Guangdong?, Taiwan).

Remarks. Because the specimen in Wang (2011) was damaged (Min Wang pers. comm.), the record of the species from Guangdong is unconfirmed.

Timandra convectaria Walker, 1861

Figs 7, 25, 41, 48, 65

Timandra convectaria Walker, 1861: 800. Holotype ♂, India: Bangladesh: Sylhet (NHM).

Calothysanis convectaria: Prout 1934: 56.

Diagnosis. The medial line of the forewing arises from the inner side of the apex in *T. convectaria*, *T. correspondens*, *T. adunca*, and *T. quadrata*. However, *T. convectaria* is dis-

tinctive from *T. correspondens*, *T. adunca*, and *T. quadrata* as follows: a sharp protrusion is present on the frons of *T. convectaria*, *T. correspondens*, and *T. adunca*, while it is absent in *T. quadrata*; the middle part of the postmedial line of the hindwing is protruded outside in *T. convectaria* and *T. quadrata*, but it is straight in *T. correspondens* and *T. adunca*. In the male genitalia, *T. convectaria* and *T. quadrata* share the short process-like uncus and the flat apex of the valvula, while the uncus is raised and the apex of the valvula is rounded in *T. correspondens* and *T. adunca*; the arm between the valvula and the sacculus in *T. convectaria* is slightly shorter in the left side than in the right side, while in other three species, these arms are symmetrical, and more strongly curved in *T. adunca*; the costa of the valvula is broadened and protruding outwards in the basal half in *T. convectaria*, while it is strongly angled centrally in other three species; the cornutus is present as a narrow stripe in *T. convectaria*, but absent in *T. correspondens*, *T. adunca*, and *T. quadrata*. In the female genitalia, the seventh sternite is strongly sclerotized and divided into one large and one small sclerite in *T. convectaria*, but it is composed of a large sclerite with bifurcate apex on the posterior margin in *T. correspondens* and *T. adunca*. The ductus bursae of *T. convectaria* is much narrower than that of *T. correspondens* and *T. adunca*.

Material examined. **INDIA** (NHM): 1♂, holotype, Sikim, N.W. India. **CHINA:** **Zhejiang** (IZCAS): 1♂, Jiangshan, Xingdun, 608 m, 10–12.VIII.2016, coll. Li Xinxin; 1♀, Zhoushan, Putuoqu, Taohuadao, 40 m, 2016.VIII.4, coll. Li Xinxin. **Hubei** (IZCAS): 1♀, Shennongjia, Jiuchong, 870 m, 19.VII.1998, coll. Ye Chanjuan. **Fujian** (IZCAS): 1♀, Nanjing, Tiankui, 6.XI.1980, coll. Zhang Baolin; 1♂, Wuping, Liangye Shan, Kongxia, 480–627 m, 17–19.XI.2008, coll. Chen Fuqiang. **Hainan** (IZCAS): 2♂, Baisha, Nankai, 270 m, 20–22.XI.2009, coll. Yang Chao. **Guangxi** (IZCAS): 1♂, Napo, Defu, 1350 m, 18.VI.2000, coll. Li Wenzhu et al.; 1♂, Longzhou, Nonggang conservation area, 195 m, 15–17.VII.2013, coll. Liu Shuxian; 1♀, Mao'er Shan, Gaozhai, 448 m, 13–15.VIII.2012, coll. Yang Chao; 2♂, Luchuan, Wenquan, Zhongxing, 198 m, 10.IV.2011, coll. Yang Xiushuai. **Sichuan** (IZCAS): 2♂, Emei Shan, Qingyinge, 800–1000 m, 25.IV.1957, coll. Wang Zongyuan et al. **Yunnan** (IZCAS): 1♂, Wanding, 900 m, 10.VI.1992, coll. Xue Dayong.

Distribution. China (Zhejiang, Hubei, Hunan, Fujian, Hainan, Taiwan, Guangxi, Sichuan, Yunnan, Tibet), Russia, Japan, Korean Peninsula, India, Bangladesh, Vietnam, Philippines.

Timandra correspondens Hampson, 1895

Figs 8, 26, 49, 66

Timandra correspondens Hampson, 1895: 459. Syntypes, India: Dharmasala (NHM).
Calothyssanis correspondens: Prout 1934: 56.

Diagnosis. This species is very similar to *T. adunca* in the external characters: the postmedial line of the hindwing is without protrusion and straight; a sharp protrusion is present on the frons. Reliable identification of *T. correspondens* and *T. adunca* is possi-

ble using the genital characters: in the male genitalia, the arm between the valvula and the sacculus is less curved in *T. correspondens* than that in *T. adunca*, and reaches to the apex of the sacculus. The seventh sternite of the female *T. correspondens* is broader than that of *T. adunca*; the colliculum of *T. correspondens* is longer than that of *T. adunca*.

Material examined. CHINA: Tibet (IZCAS): 1♀, Cona Xian, Mama, 2900 m, 6.VIII.1974, coll. Huang Fusheng; 1♀, Zayü, 2070 m, 2.VIII.1973; 1♂, Mêdog, Gutang, 2000 m, 3.X.1982, coll. Han Yinheng; 1♀, Mêdog, Baibung, 871 m, 17–18.VIII.2006, coll. Lang Songyun; 1♀, Mêdog, 1091 m, 22.VIII.2006, coll. Lang Songyun; 1♂, Zayü, Shang Zayü, 1960 m, 21–23.VIII.2005, coll. Wang Xuejian; 13♂2♀, Bomi, Tongmai, 2079–2100 m, 31.VIII.2005, 29–30.VIII.2006, coll. Wang Xuejian et al.

Distribution. China (Yunnan, Tibet), India, Burma, Vietnam.

Timandra adunca sp. n.

<http://zoobank.org/D54940B3-DF94-4F82-984A-6F3A92A150A6>

Figs 9, 27, 50, 67

Description. *Head.* Antennae bipectinate in basal four-fifths in male, filiform in female; pectination covered with ciliae, black on basal part; dorsal surface of shaft deep brown with base reddish-brown. Frons yellowish-brown to deep yellowish-brown with ventral side yellowish-white, protruding with a sharp protrusion. Labial palpi yellowish-brown, sometimes reaching to tip of frons. Vertex pale yellowish-brown. *Thorax.* Patagia brown. Tegulae and thorax pale yellowish-brown. Fore leg with reddish-brown scales on dorsal side. Hind tibia with two pairs of spurs in male. Forewing length: male 14–17 mm, female 15–16 mm. Apex of forewing acute, slightly protruding; outer margin nearly straight; hindwing with sharpened apical angle; outer margin angled on vein M_3 . Wing colour pale yellowish-brown covered with brown spots, costa of forewing dark brown with red suffusion. Forewing with deep reddish-brown and nearly triangular discal spot; medial line reddish-brown, straight and narrow, arising from inner side of apex and extending to middle part of terminal margin; postmedial line grey and narrow, separating from medial line on vein M_1 , slightly curved; fringes reddish-brown with blackish-brown at tip. Hindwing with medial and postmedial lines straight and narrow, the former reddish-brown and the latter grey; fringes similar to those of forewing. Underside with dark brown speckles; postmedial line on hindwing more distinct than on upperside.

Male genitalia. Uncus raised. Socii present as a pair of narrow digitiform processes, beyond tip of uncus. Valvula with costa dilated at apex; arm between valvula and sacculus long and hook-like, extending beyond distal end of sacculus; sacculus very broad, rounded and densely covered with short setae terminally. Juxta long and narrow at terminal half. Saccus long and rounded at apex. Aedeagus slender and curved, without cornutus.

Female genitalia. Seventh sternite trapezoid and strongly sclerotized with weakly bifurcate posterior margin. Colliculum short and narrow. Ductus bursae membranous

with a membranous appendix bursae on posterior part, about two-fifths length of corpus bursae. Corpus bursae elongate oval; signum consists of a triangular pouch directed towards anterior part, with a longitudinal ridge running from apex.

Diagnosis. See *T. correspondens*.

Type material. Holotype, ♂, **CHINA: Yunnan** (IZCAS): Ruili, Wanting forest park, 900 m, 29.IV.2011, coll. Yang Xiushuai and Wang Ke. Paratypes: **Guangxi** (IZCAS): 2♂, Longsheng, Baiyan, 1150 m, 20.VI.1963, coll. Wang Chunguang; 1♀, Mao'er Shan, Antangping, 1579 m, 17–18.VIII.2012, coll. Yang Chao; 1♀, Huanjiang, Yangmeiao, 1189 m, 18–22.VII.2015, coll. Jiang Nan. **Guizhou** (IZCAS): 3♂, Panxian, Hongguozhen, Pengjiakou, 2065 m, 6–8.VII.2016, coll. Ban Xiaoshuang. **Yunnan** (IZCAS): 1♂, Lushui, Pianma, 1980 m, 3–4.VII.2014, coll. Pan Xiaodan; 1♂, Gong Shan, Dulongjiang, 1505 m, 8–9.VII.2014, coll. Pan Xiaodan; 1♂, Lushui, Pianma, 2300 m, 30.V.1981, coll. Liao Subai; 1♂, Yingjiang, 1700 m, 16.IV.1980, coll. Li Hongxing; 1♀, Tengchong, Heinitang, 1930 m, 28–30.V.1992, coll. Xue Dayong; 1♂, Tengchong, Dahaoping, 2020 m, 5–7.VIII.2007, coll. Wu Chunguang; 1♂, Tengchong, Qushi, Daba, 1823–1873 m, 4–5.VIII.2013, coll. Liu Shuxian; 1♂, Tengchong Shidi, 1730 m, 3–5.VIII.2016, coll. Ban Xiaoshuang; 4♂2♀, Tengchong, Houqiao, 1620 m, 6–8.VIII.2016, coll. Ban Xiaoshuang; 3♂, Pingbian, Dawei Shan, 1500–2090 m, 18.VI.1956, 19–20.VII.2016, 4–8.VIII.2017, coll. Huang Keren et al.; 1♂1♀, Wenshan, Malipo, Tianshengqiao, 1105 m, 7, 15.XI.2003, coll. Lu Shengxian. **Vietnam** (IZCAS): 1♀, 23.XI–2.XII.2012, coll. Chen Fuqiang.

Distribution. China (Guangxi, Guizhou, Yunnan), Vietnam.

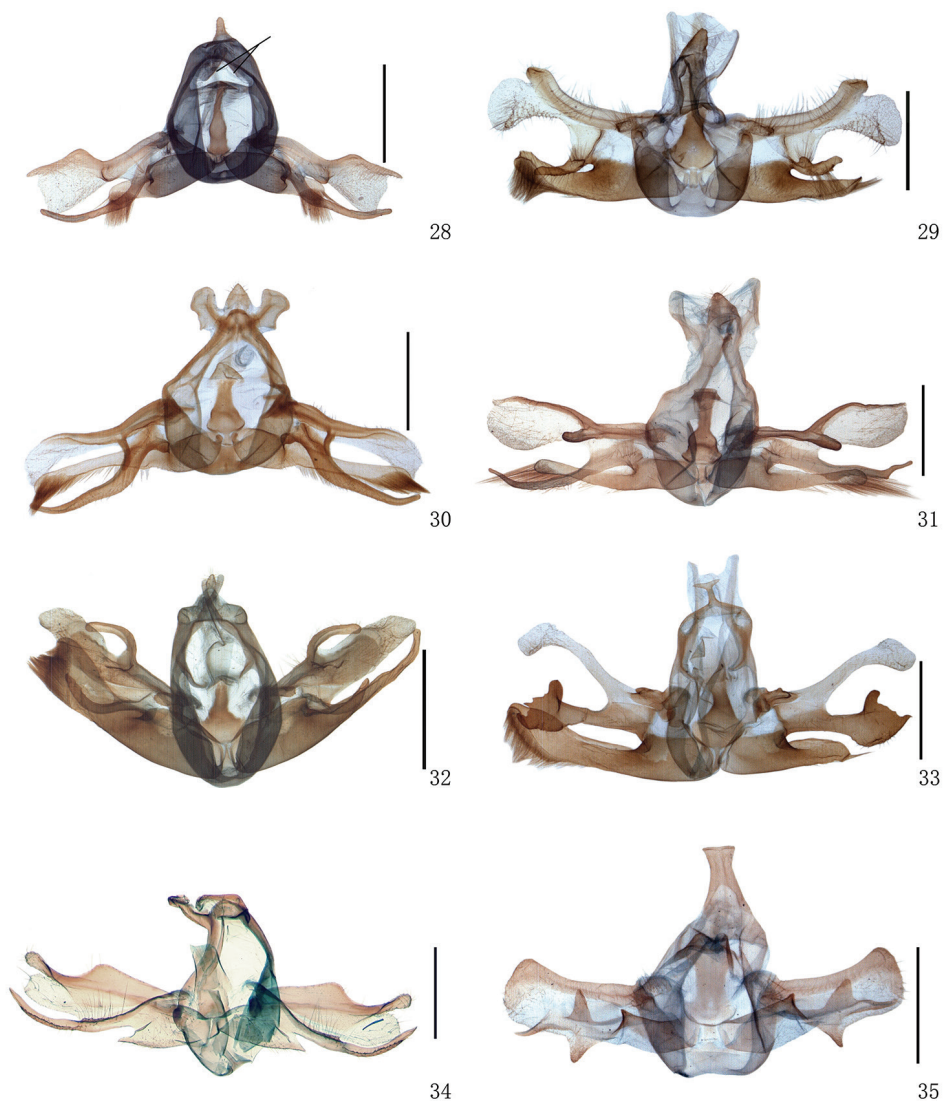
Etymology. The species is named based on the Latin *aduncus*, which refers to the hook-like arm between the valvula and the sacculus in the male genitalia.

Timandra quadrata sp. n.

<http://zoobank.org/18EDC70D-B76A-4AF5-85BD-A0CBD34D5307>

Figs 10, 28, 51

Description. *Head.* Antennae bipectinate in basal four-fifths in male, dorsal surface of shaft with reddish-brown scales, pectination yellowish-brown to blackish-brown. Frons dark yellowish-brown with ventral side yellowish-white and slightly protruding. Labial palpi yellowish-brown, not extending beyond frons. Vertex yellowish-white. *Thorax.* Patagia brown. Tegulae and thorax greyish-brown. Hind tibia with two pairs of spurs in male. Forewing length: male 14 mm. Apex of forewing pointed; outer margin weakly protruding; apex of hindwing rounded; outer margin forming a small protrusion on vein M_3 . Wing colour yellowish-brown. Forewing with costa covered with brown spots especially on basal half; antemedial line reddish-brown, very narrow and nearly straight; discal spot greyish-black and small, short bar-like; medial line reddish-brown; postmedial line greyish-brown, separated from medial line on vein M_1 , slightly protruding between M_2 and CuA_1 ; two blackish-brown spots present on veins R_4 and R_5 outside postmedial line; terminal line and fringes reddish-brown. Hindwing with medial line reddish-brown



Figures 28–35. Male genitalia of *Timandra*. **28** *T. quadrata* sp. n., black bars show the socii, Henan **29** *T. accumulata* sp. n., holotype, Yunnan **30** *T. comptaria*, Hubei **31** *T. paralias*, Hebei **32** *T. viminea* sp. n., holotype, Yunnan **33** *T. oligoscia*, Yunnan **34** *T. ruptilinea*, Guangdong **35** *T. extremaria*, Hubei. Scale bar: 1 mm.

and straight; postmedial line grey, slightly protruding between M_3 and CuA_1 ; fringes similar to those of forewing. Underside densely covered with brown speckles; stripes deep brown; discal spot and postmedial line more distinct than those on upperside.

Male genitalia. Uncus short, finger-like. Socii digitiform, short and broad, slightly beyond uncus. Costa broad at basal half, forming a right angle at terminal half, acute at apex; apex of valvula quadrate; a long, slightly curved digitiform arm stretching from

cleft between valvula and sacculus; sacculus short, approximately half as long as valvula, narrow at apical one-third, rounded and setose at apex. Juxta long and narrow, tapered in terminal half. Saccus rounded at apex. Aedeagus slightly curved; vesica without cornutus.

Female genitalia. Unknown.

Diagnosis. *T. quadrata* is very closely related with *T. convectaria*, the medial line of the forewing is weakly curved, while it is absolutely straight in *T. convectaria*; a sharp protrusion is absent in *T. quadrata*, while it is present in *T. convectaria*; the postmedial line of the hindwing is less protruded in *T. quadrata* than in *T. convectaria*. The male genitalia of *T. quadrata* are also similar to those of *T. convectaria*, but the socii are slightly stouter than those of *T. convectaria*; the costa of the valvula is strongly angled centrally in *T. quadrata*, but straight in *T. convectaria*; the sacculus is much shorter in *T. quadrata* than in *T. convectaria*; the cornutus is absent in *T. quadrata*, but is present as a long stripe in *T. convectaria*. For more comparisons, see *T. convectaria* above.

Type material. Holotype, ♂, **CHINA: Hubei** (IZCAS): 1♂, Shennongjia, Honghua, 860 m, 17.VIII.1981, coll. Han Yinheng. Paratype: **Henan** (IZCAS): 1♂, Baiyun Shan conservation area, 1550 m, 13–15.VIII.2008, coll. Xue Dayong.

Distribution. China (Henan, Hubei).

Etymology. The species is named based on the Latin *mancus*, which refers to the absence of the socii in the male genitalia.

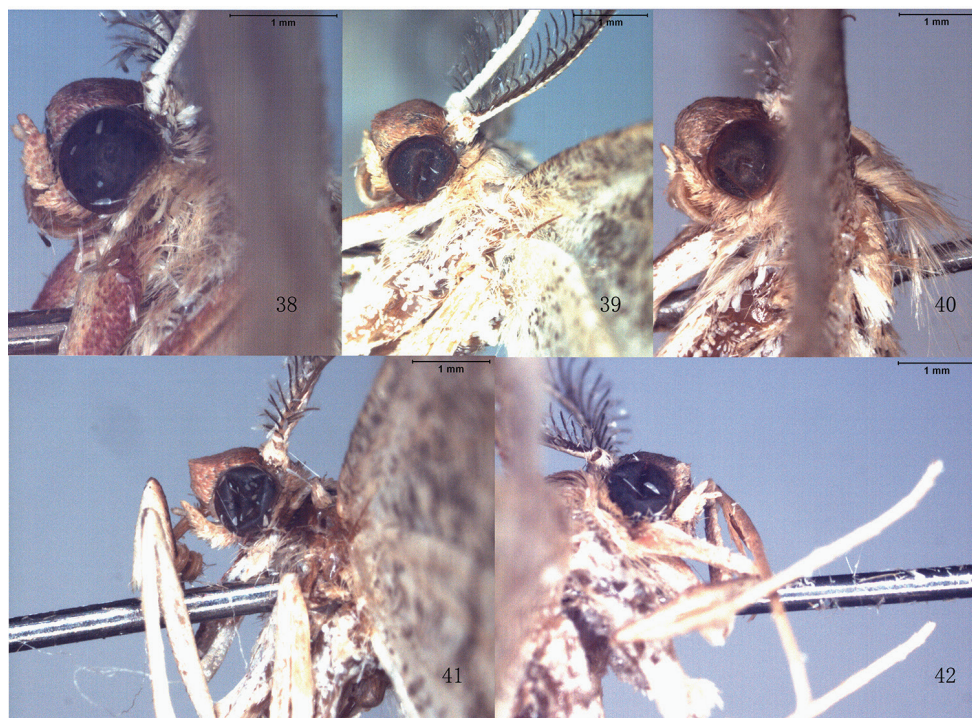
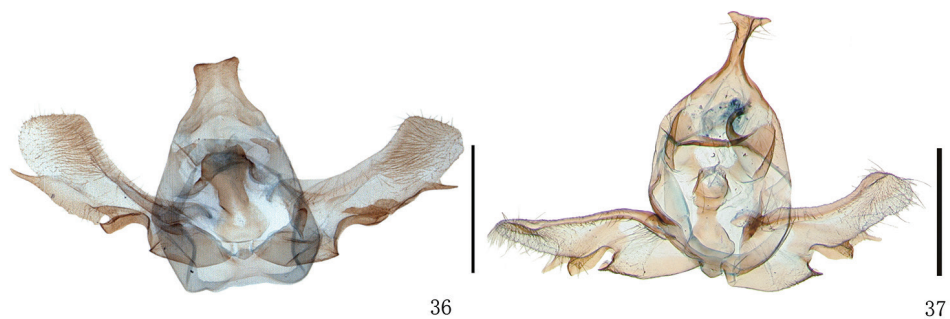
Timandra accumulata sp. n.

<http://zoobank.org/B5F05596-0DED-4340-AB87-26F28551E800>

Figs 11, 29, 40, 52, 68

Description. *Head.* Antennae bipectinate in basal five-sixths in male, filiform in female; dorsal surface of shaft pale yellowish-brown with brown scales except in basal part. Frons blackish-brown, mixed with yellowish-white on ventral side, forming a rounded protrusion (Fig. 40). Labial palpi yellowish-brown, not extending beyond frons. Vertex yellowish-white. *Thorax.* Patagia deep brown. Tegulae and thorax greyish-brown. Hind tibia with two pairs of spurs in male. Forewing length: male 16–18 mm. Forewing with acute apex; outer margin almost straight; apex of hindwing rounded; outer margin protruding on vein M_3 . Wing colour pale yellowish-brown densely scaled with greyish-brown spots. Forewing with indistinct antemedial line angled at cell; discal spot greyish-brown and short bar-like; medial line deep brown and oblique, raising from apex and extending to middle part of terminal margin, gradually broadening towards termen; postmedial line greyish-brown, overlapping with medial line at apex, separated from it before R_5 , slightly protruding; terminal line greyish-brown and narrow; fringes yellowish-brown. Hindwing with medial line deep brown and straight; postmedial line greyish-brown, slightly curved outwards in middle part; terminal line and fringes similar to those of forewing. Underside with deep greyish-brown spots, discal spot stronger and longer than upperside; postmedial line more distinct than that on upperside.

Male genitalia. Uncus broad. Tegumen narrow. Socii straight, narrow and rod-like, slightly extending beyond tip of uncus. Costa of valva thickened and slightly



Figures 36–42. 36 Male genitalia, *T. robusta* sp. n., holotype, Yunnan 37 Male genitalia, *T. stueningi* sp. n., holotype, Taiwan 38–42 Frons of *Timandra*. 38 *T. recompta* 39 *T. distorta* sp. n. 40 *T. accumulata* sp. n. 41 *T. convectaria* 42 *T. viminea* sp. n. Scale bar: 1 mm.

curved at terminal half, quadrate apically; valvula forming a rounded protrusion and with bristles at apex, arm between valvula and saccus short and digitiform with teeth on ventral margin, a small process present on base of costa, covered with bristles; saccus slightly shorter than valvula and asymmetrical, right side slightly shorter than left side, apex of right side acute and rounded on left side; densely covered with long bristles terminally. Juxta with broad base, tapered towards terminal part. Saccus broad and rounded at apex. Aedeagus short, a long sclerotized band present on vesica.

Female genitalia. Seventh sternite sclerotized, bifurcate at middle and forming two rounded lateral processes on posterior margin. Colliculum long. Ductus bursae short and membranous. Corpus bursae oval; signum present as a triangular pouch directed towards anterior part, with a longitudinal ridge running from apex.

Diagnosis. The species is characterized by the very dense greyish-brown spots on the wings, which is similar to *T. rectistrigaria* (Eversmann, 1851), but the male and female genitalia of these two species are quite different (Hausmann 2004: fig. 177). The male genitalia are characterized by the following features: the uncus is stout; the socii are narrow and straight; the costa of the valvula is slightly curved, the arm between the valvula and the sacculus is short; the right side of the sacculus is shorter than the left side and acute apically; the left side of the sacculus is rounded apically. The female genitalia are similar to those of *T. recompta*, but the seventh sternite of *T. accumulata* is broader, the colliculum is longer in *T. accumulata*, and the appendix bursae of *T. accumulata* is absent.

Type material. Holotype, ♂, **CHINA: Yunnan** (IZCAS): Lijiang, Yulong Shan, 10.VII.1962, coll. Song Shimei. Paratypes: 2♂, same as holotype, 21.VII.1962, coll. Song Shimei. **Yunnan** (ZFMK): 73♂13♀, Yunnan, Li-kiang, 6.VI–31.VIII.1934, 3–24.VII.1935, 12.VI.1935, 20.VI.1935, 21.IX.1935, 3.IX.1935, coll. H. Höne.

Distribution. China (Yunnan).

Etymology. The species is named based on the Latin *accumulatus*, which refers to the dense pattern of brown spots accumulated on the wing surface.

***Timandra comptaria* Walker, 1863**

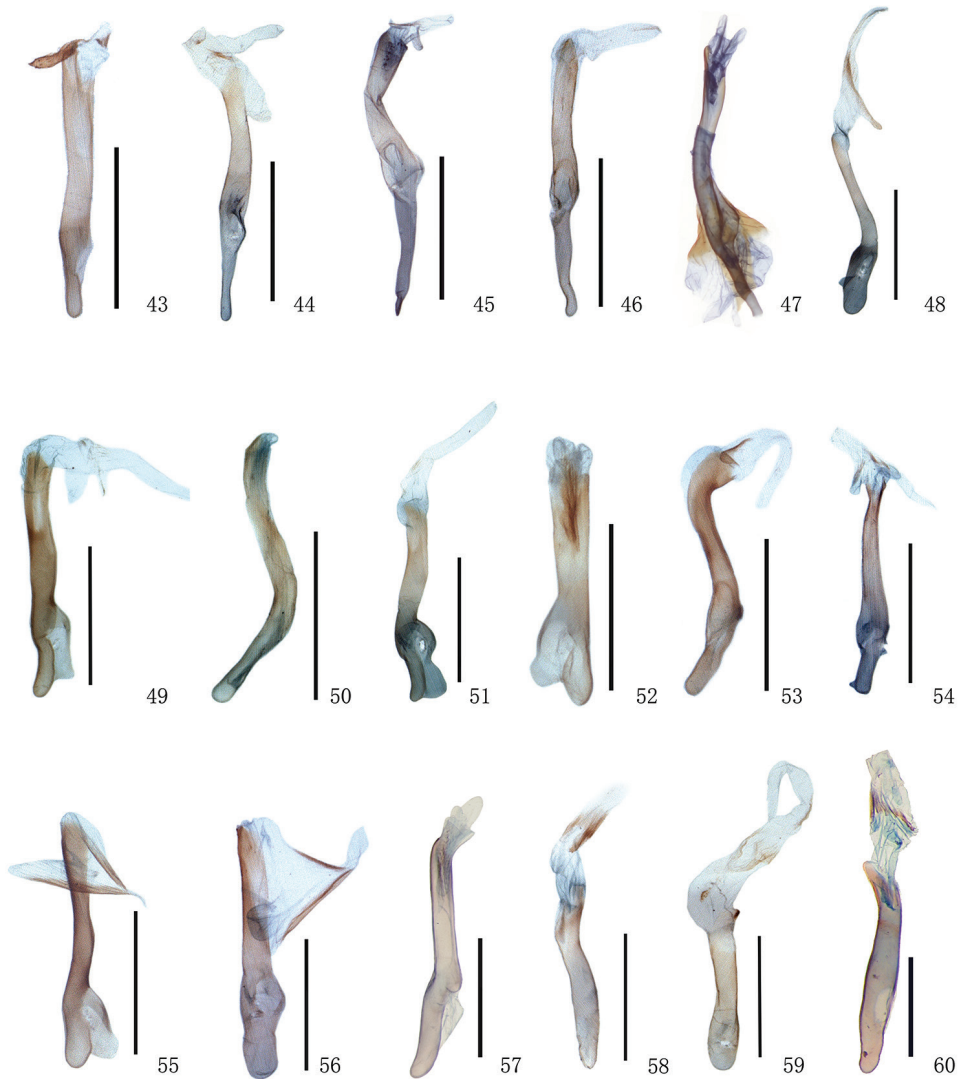
Figs 12, 30, 53, 69

Timandra comptaria Walker, 1863: 1615. Syntypes 1♂1♀, China; Hindostan [India] (NHM).

Timandra amata comptaria: Prout 1913: 48.

Calothysanis comptaria: Prout 1934: 55.

Diagnosis. This species is similar to *T. paralias*, but the frons is less protruded than in *T. paralias* and the postmedial line of the hindwing is close to the medial line in *T. comptaria*, while it is far from the medial line in *T. paralias*. In the male genitalia, the arms between the valvula and the sacculus are symmetrical in *T. comptaria*, but these are asymmetrical in *T. paralias* and the right arm is slightly angled terminally; the sacculus is longer than the valvula in *T. comptaria*, while it is shorter than the valvula in *T. paralias*; the apex of the aedeagus is curved in *T. comptaria*, but it is straight in *T. paralias*; the cornutus is composed of one sclerotized stripe in *T. comptaria*, while in *T. paralias*, two sclerotized stripes are present on the vesica of *T. paralias*. The seventh sternite is slightly concave in the middle of the posterior margin in *T. comptaria*, but it is produced in *T. paralias*; in the female genitalia, the colliculum is absent in *T. comptaria*, while it is short funnel-shaped in *T. paralias* (Kaila and Albrecht 1994: fig. 17).



Figures 43–60. Aedeagus of *Timandra*. **43** *T. recompta*, Gansu **44** *T. apicrosea*, Sichuan **45** *T. distorta* sp. n., holotype, Tibet **46** *T. dichela*, Hubei **47** *T. synthaca*, Taiwan **48** *T. convectaria*, Hainan **49** *T. correspondens*, Tibet **50** *T. adunca* sp. n., holotype, Guangxi **51** *T. quadrata* sp. n., Henan **52** *T. accumulata* sp. n., holotype, Yunnan **53** *T. comptaria*, Hubei **54** *T. paralias*, Heilongjian **55** *T. viminea* sp. n., holotype, Yunnan **56** *T. oligoscia*, Yunnan **57** *T. ruptilinea*, Guangdong **58** *T. extremaria*, Hubei **59** *T. robusta* sp. n., holotype, Yunnan **60** *T. stueningi* sp. n., holotype, Taiwan. Scale bar: 1 mm.

Material examined. CHINA: Taiwan (NHM): 1♂, holotype, 1933/395; 1♀, 11.V.1906, A.E. Wileman, Rothschild Bequest, 1939-1; 1♂, Kanshirei, 1000 ft. 19.IV.1906, A.E. Wileman, Wileman Coll. B. M. 1929-261. **Heilongjiang** (IZCAS): 1♂2♀, Yichuan, 20–22.VI.1957, 26.VIII.1957; 26♂6♀, Yichuan, Dailing, 390 m,

24.VI–15.IX.1957, 13.VI–5.IX.1958, 26.VII.1959, 11.VIII.1959, 8.VI–6.VII.1962, coll. Bai Jiuwei et al.; 2♂1♀, Xiaoling, 30.VII.1938; 1♀, Wuchang, 7.VII.1970. **Jilin** (IZCAS): 3♂, Manjiang, 11, 17.VIII.1955. **Beijing** (IZCAS): 4♂6♀, Sanpu, 18–21. VIII.1964, 14.IX.1964, coll. Liao Subai; 1♂, Xiang Shan, 16.VIII.1957; 1♂, Yingtaogou, 29.VI.1990, coll. Zhao Jie; 1♀, Mentougou, Liyuanling, 1100 m, 11–12. VIII.2004, coll. Li Hongmei. **Hebei** (IZCAS): 1♂, Wuling Shan, 4.VIII.1981, coll. Gong Heng. **Shaanxi** (IZCAS): 2♂2♀, Fengxian, source of Jialingjiang, 1510 m, 21–24.VII.2017, coll. Cui Le; 1♂, Shangnan, gate of Jinsixia scenic area, 766 m, 16–19.VII.2017, coll. Cui Le. **Gansu** (IZCAS): 1♂, Yongdeng, Liancheng Linchang, 25.VI.1992, coll. Meng Feng; 1♂, Wenxian, VI–IX.2002, coll. Wang Hongjian. **Shanghai** (IZCAS): 5♂4♀, 15–27.VI.1933, 15–27.VIII.1933, 6.V.1935, coll. A. Savio. **Jiangsu** (IZCAS): 1♂, Yang Chow, 1936.V.15. **Zhejiang** (IZCAS): 1♀, Jiangshan, Xingdun, 608 m, 10–12.VIII.2016, coll. Li Xinxin; 2♂1♀, Yuyao, Siming Shan, 814 m, 31.VII–2.VIII.2016, coll. Li Xinxin; 1♂, Yinzhou, Chishui, 241 m, 25.VII.2015, coll. Cheng Rui; 2♂, Pan'an, Huangtan Linchang, 891 m, 27–28. VII.2015, coll. Cheng Rui; 1♂, Tianmu Shan, 20.VII.1973, coll. Zhang Baolin; 1♀, Jinyun, VII.1981; 1♂1♀, Qingyuan, Fengyang Shan, Datianping, 1290 m, 6–10. VIII.2003, coll. Han Hongxiang. **Hubei** (IZCAS): 1♂5♀ (Shennongjia, Dajiuhu, 1800 m, 1–5.VIII.1981, coll. Han Yinheng. **Jiangxi** (IZCAS): 2♀, Guling, VII.1935, 19.VIII.1935; 1♀, Lu Shan, 17.VI.1974, coll. Zhang Baolin; 1♀, Jiulian Shan, 23.VI.1975, coll. Song Shimei. **Hunan** (IZCAS): 1♂1♀, Anhua, 25.VIII.1981; 4♂, Hengyang, Nanyue Linchang, 13.VII.1980, 6–28.IX.1980, coll. Li Jutao et al.; 1♂1♀, Mang Shan, 30.VI.1981, 13.VII.1981. **Fujian** (IZCAS): 1♂1♀, Nanping, Xiadao, 27–28.V.1963, coll. Zhang Youwei; 2♂1♀, Jianyang, Huangkeng, 270 m, 30.VI–1. VII.1973, coll. Zhang Bailin; 1♂, Jianyang, Huangkeng, Aotou, 25.VI.1980, coll. Jiang Fan; 1♂, Jiangyang, Chengguan, 90–120 m, 12.VIII.1960, coll. Ma Chenglin; 1♀, Jianou, Dongfeng, 27.X.1980; 1♂, Wuyi Shan, 25.IV.1982, coll. Zhang Baolin; 1♀, Wuyi Shan, Sangang, 704 m, 11–14.VIII.2009, coll. Xue Dayong; 1♂, Meihua Shan, Yunshan, 459 m, 18.VII.2013, coll. Yang Chao. **Guangdong** (IZCAS): 1♀, Shixing, Chebaling, 330 m, 1–2.VIII.2013, coll. Xue Dayong. **Sichuan** (IZCAS): 10♂10♀, Emei Shan, Qingyinge, 800–1000 m, 16.IV–15.VII.1957, 17–22.IX.1957, coll. Zhu Fuxing et al.; 1♂, Emei Shan, Jiulaodong, 1800–1900 m, 14.VIII.1957, coll. Zhu Fuxing; 1♂, Guanxian, Qingcheng Shan, 700–1600 m, 30.V.1979, coll. Gao Ping; 1♀, Wanxian, Wang'erpu, 1200 m, 27.IX.1994, coll. Song Shimei. **Chongqing** (IZCAS): 1♀, 14.VI.1974, coll. Han Yinheng; 1♀, Beibei, 14.V.1999, coll. Wang Haijian et al. **Yunnan** (IZCAS): 1♀, Jingdong, 1170 m, 2.VI.1956, coll. A.K. Zaguljaev; 1♂, Menglong, Bannan, Mengsong, 1600 m, 24.IV.1958, coll. Meng Xuwu; 1♀, Zhenxiong, Machang, 1820 m, 24.VII.1982, coll. Luo Zhengjin; 5♂3♀, Menglong, Bannan, Mengso, 1930 m, 28–30.V.1992, coll. Xue Dayong.

Distribution. China (Heilongjiang, Jilin, Beijing, Hebei, Shaanxi, Gansu, Shanghai, Jiangsu, Zhejiang, Hubei, Jiangxi, Hunan, Fujian, Taiwan, Guangdong, Sichuan, Chongqing, Yunnan), Russia, Korean Peninsula, Japan, India.

***Timandra paralias* (Prout, 1935)**

Figs 13, 31, 54

Calothysanis paralias Prout, 1935: 28, pl. 4, fig. c. Holotype ♂, Russia: Siberia (east), Vladimir Bay, at mouth of river (NHM).

Timandra paralias: Kaila and Albrecht 1994: 461.

Diagnosis. In the male genitalia, *T. paralias* is unique by the angled apex of the right arm between the valvula and the sacculus. For more detailed comparisons with *T. comptaria*, see *T. comptaria*.

Material examined. CHINA: Heilongjiang (IZCAS): 3♂, Yichun, Dailing, 390 m, 15.VII.1958, 26.VII.1959, 11.VIII.1959, coll. Zhou Shixiu et al. Inner Mongolia (IZCAS): 1♂, Jiwen, 16.VII.1982; 2♂, Chifeng, Eqi, 12–14.VII.1987, coll. Liu Chunxiang et al. Hebei (IZCAS): 1♂, Xiaowutai Shan, Nantai, 1700 m, 7.VII.1964, coll. Wang Chunguang; 1♂, Chicheng, Longmensuo, Liuzhuangzi, 10–11.VIII.2006, coll. Yang Chao.

Distribution. China (Heilongjiang, Inner Mongolia, Hebei), Russia (Siberia).

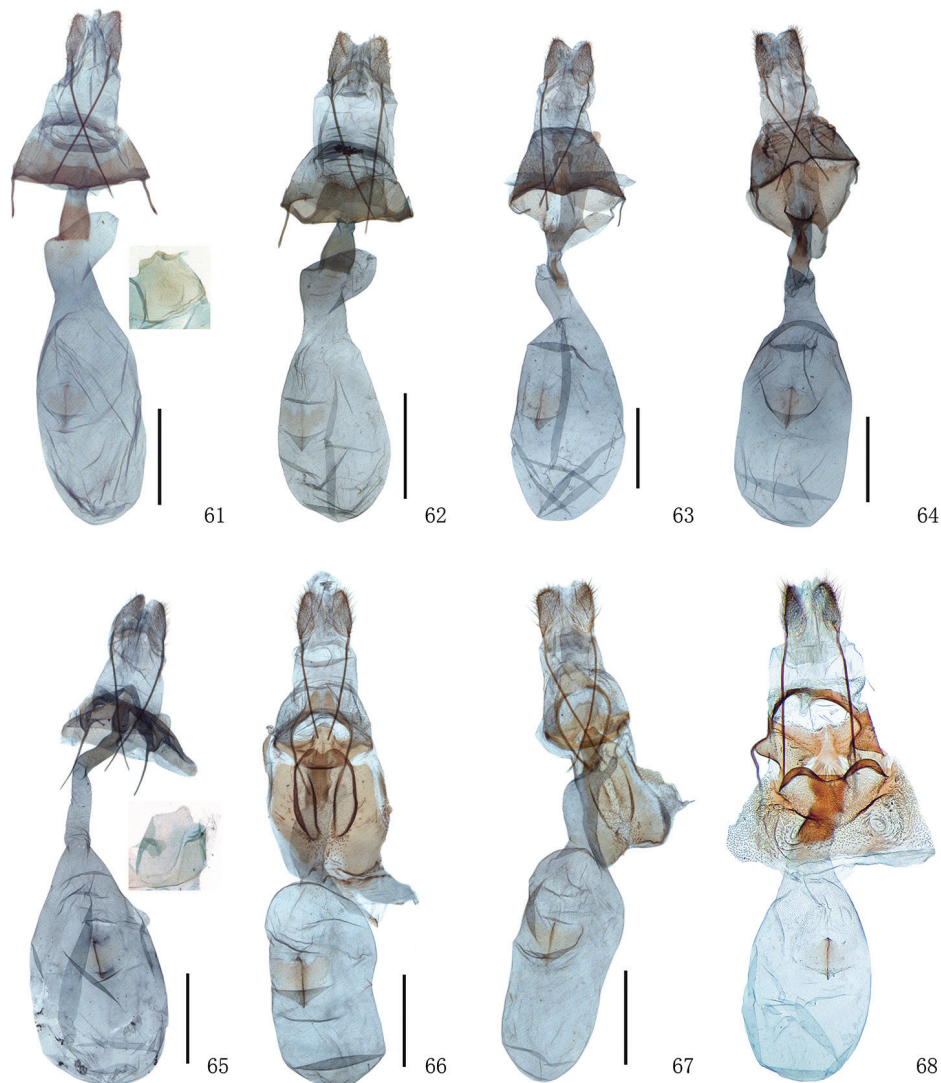
***Timandra viminea* sp. n.**

<http://zoobank.org/9942C321-7E9D-4FDA-96CA-597FE443E659>

Figs 14, 32, 42, 55, 70

Description. *Head.* Antennae bipectinate to five-sixths in male and filiform in female; dorsal surface of shaft pale yellowish-brown, slightly speckled with brown scales. Frons blackish-brown, ventral side yellowish-white and with an obtuse protrusion on ventral margin (Fig. 42). Labial palpi yellowish-brown, not extending beyond frons. Vertex yellowish-white. *Thorax.* Patagia brown. Tegulae and thorax pale yellowish-brown. Hind tibia with two pairs of spurs in male. Forewing length: male and female 12–13 mm. Apex of forewing acute and outer margin nearly straight; hindwing with rounded apex and outer margin forming a small protrusion on vein M_3 . Wing colour yellowish-brown with brown spots. Forewing with discal spot blackish-brown, small, angled at middle; medial line reddish-brown, arising from apex; postmedial line grey and narrow, separating from medial line on vein R_5 ; terminal line grey; fringes yellowish-brown, sometimes pinkish-red at apex. Hindwing with medial line reddish-brown and straight; postmedial line grey and narrow, protruding centrally; terminal line and fringes similar to those of forewing. Underside densely covered with brown speckles; postmedial line more distinct than that on upperside.

Male genitalia. Uncus broad at base, digitiform at terminal part. Socii narrow and rod-like, extending slightly beyond tip of uncus; inner margin of tegumen with a pair of acute processes centrally. Costa of valva with a digitiform and curved process centrally; a slender and curved arm present between valvula and sacculus; sacculi asymmetric, terminal part broad and narrow, covered with setae on left side, but narrow and digitiform



Figures 61–68. Female genitalia of *Timandra*. **61** *T. griseata*, Xinjiang **62** *T. recompta*, Xinjiang **63** *T. apicirosea*, Sichuan **64** *T. dichela*, Jiangxi **65** *T. convectaria*, Fujian **66** *T. correspondens*, Tibet **67** *T. adunca* sp. n., Yunnan **68** *T. accumulata* sp. n., Yunnan. Scale bar: 1 mm.

on right side. Juxta broad near base, tapered towards terminal part. Saccus small and rounded at apex. Aedeagus slender, cornuti composed of two long sclerotized stripes.

Female genitalia. Seventh sternite narrow and sclerotized, slightly concave on posterior margin. Lamella postvaginalis sclerotized. Colliculum narrow. Ductus bursae shorter than corpus bursae, strongly sclerotized on posterior part; signum with a longitudinal sclerite inwards a slightly sclerotized plate, a pouch present on anterior part.



Figures 69–74. Female genitalia of *Timandra*. **69** *T. comptaria*, Yunnan **70** *T. viminea* sp. n., Yunnan **71** *T. oligoscia*, Hunan **72** *T. ruptilinea*, Guangxi **73** *T. extremaria*, Zhejiang **74** *T. stueningi* sp. n., Taiwan. Scale bar: 1 mm.

Diagnosis. The new species can be identified by the combination of the following characters: the frons is blackish-brown with an obtuse protrusion on the ventral margin; in the male genitalia, a long digitiform and curved process is present at the middle of the costa; the sacculi are asymmetric, as the left side is much stouter than the right one; the cornuti are two long sclerotized stripes; the seventh sternite of the female is

narrow and sclerotized, and slightly concave on the posterior margin; the posterior half of the ductus bursae is strongly sclerotized.

Type material. Holotype, ♂, **CHINA: Yunnan** (IZCAS): Baoshan, Baihualing, 1520 m, 11–13.VIII.2007, coll. Xue Dayong. Paratypes: 3♂7♀, as same as holotype, coll. Wu Chunguang et al.; 3♂, Cang Shan, Puladi, 1298 m, 6–7.VII.2014, coll. Li Xinxin; 1♀, Baoshan, Bawan, 1040 m, 8–10.VIII.2007, coll. Xue Dayong.

Distribution. China (Yunnan).

Etymology. The species is named based on the Latin *vimineus*, which refers to the slender right sacculus in the male genitalia.

Timandra oligoscia Prout, 1918

Figs 15, 33, 56, 71

Timandra oligoscia Prout, 1918: 79. Syntypes ♂, China: Tibet, Vrianatong (NHM).

Calothyssanis oligoscia: Prout 1934: 56.

Diagnosis. This species can be distinguished from its congeners by the following characters: the frons is blackish-brown and slightly protruded; the postmedial line of the forewing is almost straight and separating from the medial line under the vein M_3 . In the male genitalia, the uncus is narrow and T shaped; the socii are long and extending beyond the tip of the uncus; the terminal part of the valvula is weakly sclerotized, its apex is slightly dilated and almost rectangular; the arm between the valvula and the sacculus is as long as the valvula and strongly sclerotized, its apex is dilated, plate-like with irregular serration on the apical margin; both sacculi have a rounded apex, but are asymmetric, as the left side is longer than the right one; the posterior margin of the aedeagus has several small teeth; the cornuti are developed as two sclerotized stripes. The seventh sternite of the female is large, strongly sclerotized, connected with the tergum as a ring, and forms two diverticula on the anterior margin; the colliculum in the female genitalia is stout; the ductus bursae is short and stout.

Material examined. **CHINA: Gansu** (IZCAS): 1♀, Zhouqu, Shatan Linchang, 2400 m, 15.VII.1999, coll. He Tongli. **Hubei** (IZCAS): 1♀, Shennongjia, Dajiuhe, 1800 m, 5.VIII.1981, coll. Han Yinheng. **Hunan** (IZCAS): 1♀, Zhangjiajie, Wulingyuan, Huanglonglu, 348 m, 18.IX.2015, coll. Zhao Kaidong. **Guangxi** (IZCAS): 1♂2♀, Napo, Defu, 1300–1350 m, 16.VIII.1998, 18.VI.2000, coll. Li Wenzhu et al. **Sichuan** (IZCAS): 1♀, Dukou, 22.VIII.1980, coll. Zhang Baolin; 1♂, Huili, 24.VII.1974, coll. Han Yinheng. **Yunnan** (IZCAS): 1♂2♀, Xinping, Gasa, Yaonan, 1900 m, 10–13.VIII.2017, coll. Cui Le; 1♂, Tengchong Shidi, 1697 m, 25.VI.2014, coll. Li Xinxin; 1♂, Weixi, Pantiange, 2570 m, 15–16.VII.2014, coll. Pan Xiaodan; 1♂, Dali, Cang Shan, 2226 m, 23–24.VI.2014, coll. Li Xinxin; 1♂, Changning, 25.VI.1979; 4♂, Dali, Hudiequan, 2050 m, 4.VI.1980, 16.V.1992, coll. Xue Dayong; 1♂, Dali, Zhonghe (Dali, Cang Shan), 2120 m, 12–13.VIII.2013, coll. Li Xinxin; 1♂, Tengchong, Laifeng Shan, 1620 m, 24.V.1982; 1♂, Tengchong, Qushi, Daba, 1823–1873 m, 4–5.VIII.2013, coll.

Liu Shuxian. **Tibet** (IZCAS): 1♂, Zayü, Shang Zayü, 1963 m, 30.VI–1.VII.2015, coll. Li Xinxin; 2♂, Zayü, Shang Zayü, 1960 m, 21–23.VIII.2005, coll. Wang Xuejian.

Distribution. China (Gansu, Hubei, Hunan, Guangxi, Sichuan, Yunnan, Tibet), Burma.

***Timandra ruptilinea* Warren, 1897**

Figs 16, 34, 57, 72

Timandra ruptilinea Warren, 1897: 64. Holotype ♂, India: Khasi Hills (NHM).

Timandra flavisponsaria Hampson, 1912: 1248. Syntypes, India: Madras, Wynâd; Nilgiris; Burma, Katha (NHM).

Diagnosis. This species differs from its congeners by the following characters: the wing colour of the area outside the medial line is darker than the area inside the medial line; the postmedial line of the forewing is narrow and forms black spots on the veins; the middle part of the postmedial line of the hindwing is strongly curved. In the male genitalia, the uncus is small and raised in *T. ruptilinea*, which is similar to that of *T. correspondens* and *T. adunca*; the socii are long and digitiform, extending beyond the tip of the uncus; the costa of the valva is narrow at the terminal half and rounded at the tip; the arm between the valvula and the sacculus is longer than the valvula and as long as the costa of the valva, and equipped with several small teeth on the ventral margin, except on the basal half and the subapical part; the sacculus is short and acute at the apex; the vesica of the aedeagus is weakly sclerotized and wrinkled. The seventh sternite of the female is short and bifurcated on the posterior margin; the lamella postvaginalis in the female genitalia are three quadrate lobes, the central one is less sclerotized than the lateral ones; the ductus bursae is very short, narrow, and sclerotized posteriorly.

Material examined. **CHINA: Guangdong** (loaned from ZFMK): 1♂, China mer.occ. Kwangtung sept, Lienping, ex coll. Wehrli. **Guangxi** (ZFMK): 2♂1♀, China (Kouangsi), Région da Nanning, 1929.

Distribution. China (Guangdong, Guangxi), India, Burma, Malay Peninsula.

***Timandra extremaria* Walker, 1861**

Figs 17, 35, 58, 73

Timandra extremaria Walker, 1861: 801. Holotype ♂, N China (NHM).

Timandra? sordidaria Walker, 1863: 1615 (N China).

Calothyssanis extremaria: Prout 1934: 57.

Calothyssanis extremaria xenophyes Prout, 1935: 29, pl. 4, fig. c.

Diagnosis. This species, *T. robusta* and *T. stuenningi* differ from its congeners by the following characters: the frons is fully protruded; the postmedial lines of both two wings

form black spots on the veins. In the male genitalia, the tip of the uncus is flat and the socii are absent. *T. extremaria* can be distinguished from *T. robusta* and *T. stueningi* by the following characters: the forewing is shorter and broader in *T. stueningi* than in *T. extremaria* and *T. robusta*; the outer margin of the forewing is straighter in *T. stueningi* than in *T. extremaria* and *T. robusta*; the colour of the frons is blackish-brown with reddish pigmentation in *T. extremaria*, but without reddish pigmentation in *T. robusta*. In the male genitalia, the uncus of *T. robusta* is shorter and stouter than that of *T. extremaria* and *T. stueningi*, the basal half in *T. stueningi* is narrower than in *T. extremaria* and *T. robusta*; a pair of spurs are present on the inner side of the tegumen in *T. robusta* and *T. stueningi*, while they are absent in *T. extremaria*, but in *T. stueningi*, the spurs are longer than those in *T. robusta*; a triangular process is present at the central part of the valvula in *T. extremaria*, but it is absent in *T. robusta* and *T. stueningi*; the apex of the sacculus is more acute in *T. extremaria* and *T. stueningi* than in *T. robusta*; the middle process on the ventral margin of the valvula is triangular in *T. extremaria*, but digitiform in *T. robusta* and *T. stueningi*; the vesica is more strongly sclerotized in *T. extremaria* and *T. stueningi* than in *T. robusta*. In the female genitalia, the ductus bursae of *T. extremaria* is broader than that of *T. stueningi*.

Material examined. **CHINA:** 1♂, holotype of *T. extremaria*, N. China, 54.8 (NHM). 1♂, holotype of *T. sordidaria*, N. China (NHM). **Shaanxi** (IZCAS): 1♀, Ning-shan, Huoditang, 4.VIII.1979, coll. Han Yinheng; 1♂, Ningshan, Guanghujie conservation area 1189 m, 26–28.VII.2014, coll. Ban Xiaoshuang; 1♀, Ziyang, 21.VI.1976, coll. Ma Wenzhen. **Gansu** (IZCAS): 2♂, Wenxian, VI–IX.2002, coll. Wang Hongjian; 1♀, Wenxian, Fanba, 800 m, 26.VI.1998, coll. Zhang Xuezhong; 1♀, Wenxian, Bikou, 620 m, 15–16.VIII.2014, coll. Ban Xiaoshuang; 2♂, Wenxian, VI–IX.2002, coll. Wang Hongjian; 1♂, Bikou, Bifenggou, 720 m, 8–10.VIII.2016, coll. Cheng Rui and Jiang Shan. **Shanghai** (IZCAS): 8♂3♀, 15.VI.1930, 21.VI.1933, 5–23.VIII.1933, 7.VI.1934, 17, 19.V.1935, coll. O. Piel and A. Savio. **Anhui** (IZCAS): 1♀, Sucheng, 9.VIII.1955. **Zhejiang** (IZCAS): 3♂, Lin'an, West Tianmu Shan, 400 m, 2003.VII.26–27, coll. Xue Dayong; 1♀, Hangzhou, 20.X.1980, coll. Zhang Bailin; 1♂, Tianmu Shan, Longyuan Shanzhuang, 10.V.1998, coll. Xia Weizheng; 10♂3♀, West Tianmu Shan, 30.VII–1.VIII.1972, 20–24.VII.1973, 17.X.1980, coll. Zhang Bailin et al.; 4♂, Lin'an, West Tianmu Shan, 400 m, 26–27.VII.2003, coll. Xue Dayong; 1♀, Chekiang, Chusan (Zhoushan), 27.VII.1931, coll. O. Piel; 3♂, Tianmu Shan, 7–10.VII.2007, coll. You Ping (loaned from insect specimen room of Nankai University). **Hubei** (IZCAS): 4♂, Yunxi, Guanyinzen, 289–305 m, 4–5.VIII.2014, coll. Liu Shuxian; 1♂1♀, Xingshan, Longmenhe, 730–1260 m, 22–23.VI.1993, coll. Huang Runzhi et al.; 1♂, Xingshan, Xiaohokou, 700 m, 11.V.1994, coll. Li Wenzhu. **Hunan** (IZCAS): 1♂, Heng Shan, 1980; 1♂1♀, Hengyang, Nanyue Linchang, 28.VI.1980, 3.X.1980, coll. Li Jutao et al.; 1♂, Nanyue, Shumuyuan, 12.VII.1980, coll. Li Jutao; 1♂1♀, Hengyang, Nantaisi, 24–25.VIII.1980, coll. Liu Yili et al.; 1♂, Zhangjiajie, 11.X.1988; 1♂, Guzhang, Gaowangjie, 850 m, 29.VII.1988, coll. Chen Yixin; 1♂2♀, Heng Shan, 21–29.VIII.1979, coll. Zhang Baolin; 1♀, Fenghuang Xiancheng, 362 m, 25.IX.2015, coll. Yao Jian; 1♀, Fenghuang, Nanhua Shan, 456 m, 26.IX.2015, coll. Zhao Kaidong; 1♀, Shimen, Huping Shan, Nanping, Maozhuhe, 320 m, 15–17.X.2014, coll. Yao Jian; 1♀, Shimen, Huping Shan,

Daling, 444 m, 18–20.X.2014, coll. Yao Jian. **Fujian** (IZCAS): 1♂, Jianou, Dongfeng, 1.II.1980; 2♀, Wuyi Shan, 4–5.VII.1982, coll. Zhang Kechi et al. **Taiwan** (NHM): 1♂, Kanshirei, Formosa, 1000 ft. 2.VIII.1906, A.E. Wileman, Wileman Coll. B. M. 1929–261. 1♀, Kanshirei, Formosa, 1000 ft. 20.IV.1906, A.E. Wileman, Wileman Coll. B. M. 1929–261. **Guangxi** (IZCAS): 2♂, Ziyuan, 14.VII.1976, coll. Zhang Baolin; 1♂1♀, Longsheng, 13.VI.1980, coll. Song Shimei; 1♂, Napo, Defu, 1350 m, 19.VI.2000. **Sichuan** (IZCAS): 28♂15♀, Emei Shan, Qingyinge, 800–1000 m, 29.IV–26.VII.1957, 17–22.IX.1957, coll. Zhu Fuxing et al.; 1♀, Emei Shan, Baogusi, 550–750 m, 24.IV.1957, coll. Wang Zongyuan; 5♂1♀, Emei Shan, 580–1100 m, 20–21.VI.1955, 11.VI.1974, 19.VI.1979, 29.VIII.1980, coll. Li Jinhua et al.; 1♀, Lu Shan, 31.VII.1980, coll. Zhang Baolin; 1♂1♀, Huili, 1900 m, 10.X.1960, 31.VII.1974, coll. Meng Xuwu et al.; 2♂, Guanxian, Qingcheng Shan, 700–1600 m, 23.VI.1963, 4.VI.1979, coll. Zhang Xuezhong et al.; 2♂2♀, Xichang, 29–31.VII.1980, coll. Zhang Baolin. **Guizhou** (IZCAS): 1♂, Leishan, Leigong Shan, 1650 m, 2.VII.1988, coll. Yuan Dechang.

Distribution. China (Shaanxi, Gansu, Shanghai, Anhui, Zhejiang, Hubei, Hunan, Fujian, Taiwan, Guangxi, Sichuan, Guizhou).

***Timandra robusta* sp. n.**

<http://zoobank.org/5D00CE17-814D-4D32-92AB-CD98AEE1DA01>

Figs 18, 36, 59

Description. *Head.* Antennae bipectinate in basal four-fifths in male; dorsal surface of shaft pale yellowish-brown with brown scales to tip gradually. Frons deep yellowish-brown and slightly protruding. Labial palpi yellowish-brown, not extending beyond frons. Vertex yellowish-white, sometimes mixed with brown centrally. *Thorax.* Patagia brown. Tegulae and thorax greyish-brown. Hind tibia with two pairs of spurs in male. Forewing length: male 18–19 mm. Forewing with pointed apex; outer margin almost straight; hindwing with rounded apex; outer margin protruding on vein M_3 . Wing colour yellowish-brown. Forewing with discal spot black and weak; medial line brown, straight, arising from apex and extending to middle part of terminal margin; postmedial line grey, straight, narrow and weak, forming a row of small black spots on veins, separating from medial line before vein M_1 ; terminal line brown; fringes yellowish-brown. Hindwing with medial line brown, straight; postmedial line arched, similar to that of forewing; terminal line and fringes similar to those of forewing. Underside with terminal line of forewing, postmedial line of hindwing and discal spot of forewing more distinct than those on upperside.

Male genitalia. Uncus short and stout, slightly concave at tip. Socii absent. A pair of short spurs present on inner side of tegumen. Base of ventral margin of valvula with two short processes, basal one stouter than subapical one. Saccus short with acute apex. Juxta broad on basal and terminal part, narrow centrally. Saccus short and broad, terminally flattened. Aedeagus short and narrow; vesica membranous, but partly weakly sclerotized, with two small sclerotized protrusions, covered with spurs on surface.

Female genitalia. Unknown.

Diagnosis. See the diagnosis of *T. extremaria*.

Type material. Holotype, ♂, **CHINA: Yunnan** (IZCAS): Baoshan, Baihualing, 1520 m, 11–13.VIII.2007, coll. Wu Chunguang. Paratype: **Yunnan** (IZCAS): 1♂, Jingdong, 1170 m, 1.VI.1956, coll. A.K. Zaguljaev.

Distribution. China (Yunnan).

Etymology. The species is named based on the Latin *robustus*, which refers to the short and stout uncus in the male genitalia.

***Timandra stueningi* sp. n.**

<http://zoobank.org/872AB617-27B0-4912-9204-50C1BDD94EF8>

Figs 19, 37, 60, 74

Description. *Head.* Antennae bipectinate in male; dorsal surface of shaft pale yellowish-brown with brown scales, except in basal part; filiform in female. Frons reddish-brown, scaled with yellowish-white on ventral side, not protruding. Labial palpi yellowish-brown, slightly extending beyond frons. Vertex yellowish-white. *Thorax.* Patagia greyish-brown. Tegulae and thorax greyish-brown. Hind tibia with two pairs of spurs in male. Forewing length: male and female 17–19 mm. Forewing with acute apex, slightly protruded, outer margin straight; hindwing with rounded apex, outer margin protruding on vein M_3 . Wing colour yellowish-brown, densely covered with blackish or greyish-brown spots. Forewing with discal spot nearly invisible, greyish-brown; medial line arising from apex, narrow and black apically, then reddish-brown and straight, broad below vein R_5 ; postmedial line composed of black spots on veins and connected with greyish-brown thin line; terminal line pale brown; fringes yellowish-brown. Hindwing with medial line similar to that of forewing; postmedial line arched, similar to that of forewing; terminal line and fringes similar to those of forewing. Underside densely covered with black speckles, stripes blackish-brown. Postmedial line of all wings and discal spot of forewing more distinct than those on upperside.

Male genitalia. Uncus narrow, dilated at terminal part, resembling fishtail. Socii absent. Tegumen with a pair of long and curved spine-like processes on inner side. Costa narrow; valvula rounded at apex, with two short processes centrally, basal one stout and rounded at tip, apical one narrow and acute terminally; sacculus approximately two times shorter than valvula, acute at tip. Juxta rounded at base, middle part slightly narrower than terminal part. Saccus small. Aedeagus slightly curved terminally; vesica with a weakly sclerotized and ribbed band.

Female genitalia. Seventh sternite membranous. Sterigma large, widely concave at middle of posterior margin. Colliculum short. Ductus bursae slender, approximately half as long as corpus bursae. Corpus bursae long and oval; signum with a longitudinal sclerite inside a slightly sclerotized plate, a pouch present on anterior part.

Diagnosis. See *T. extremaria*.

Type material. **CHINA: Taiwan:** Holotype (ZFMK), ♂, Chilan (Ilan Cy), 600 m, 16.VI.1993, coll. F. Aulombard and J. Plante. Paratypes: **Taiwan:** 1♂, Tibn hsiang,

Hualien Co., 600 m, 19/21.VI.1993, coll. F. Aulombard and J. Plante (loaned from ZFMK); 1♀, Lishan, Taichung Co., 2020 m, 23/30.IX.1992, coll. F. Aulombard and J. Plante (loaned from ZFMK); 1♂, Hueisun Forest, Nantou Co., 570/800 m, 28/29.IX.1992, coll. F. Aulombard and J. Plante (ZFMK); 1♀, Tien-Hsiang (Hualien Co.), 600 m, 20.VI.1993, coll. F. Aulombard and J. Plante (ZFMK). **Taiwan** (TFRI): 1♀, Taipei Co., Xindian, Wulai, Fushan, 310 m, 9.VI.2013, leg. S. Wu; 2♂, Miaoli Co., Nanchuang, Henawan, 850 m, 10.XI.2018, leg. S. Wu; 1♂, Taichung Co., Wuling, 1800 m, 12.IX.2012, leg. S. Wu; 1♂, ditto, 24.X.2014, leg. S. Wu; 1♂, Hualien, Ci'en, 1950 m, 10.XI.2012, leg. S. Wu; 1♀, Chiayi Co., Dabon, 1400 m, 16.VI.2013, leg. S. Wu and W. C. Chang; 1♀, Chiayi Co., Shanmei, 800 m, 9.III.2011, leg. S. Wu and W. C. Chang; 1♀, ditto, 6.X.2011, leg. S. Wu and W. C. Chang; 1♀, Kaohsiung Co., Shanping, 650 m, 3.V.2014, leg. W. C. Liao; 2♂1♀, Taitung Co., Taimali, 26.II.2014, leg. Y. C. Lin.

Distribution. China (Taiwan).

Etymology. The species is dedicated to Dr Dieter Stüning, Bonn, Germany, who has contributed greatly to the taxonomy of the Geometridae.

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A new species of sardine, *Sardinella pacifica* from the Philippines (Teleostei, Clupeiformes, Clupeidae)

Harutaka Hata¹, Hiroyuki Motomura²

1 The United Graduate School of Agricultural Sciences, Kagoshima University, 1–21–24 Korimoto, Kagoshima 890–0065, Japan **2** The Kagoshima University Museum, 1–21–30 Korimoto, Kagoshima 890–0065, Japan

Corresponding author: Hata Harutaka (k2795502@kadai.jp)

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Abstract

A new sardine, *Sardinella pacifica* **sp. n.**, is described on the basis of 21 specimens collected from the Philippines. The new species closely resembles *Sardinella fimbriata* (Valenciennes, 1847), both species having lateral scales with centrally discontinuous striae, a dark spot on the dorsal-fin origin, more than 70 lower gill rakers on the first gill arch, the pelvic fin with eight rays, and 17 or 18 prepelvic and 12 or 13 postpelvic scutes. However, the new species is distinguished from the latter by lower counts of lateral scales, pseudobranchial filaments, and postpelvic scutes (38–41, 14–19 and 12–13, respectively vs. 44–46, 19–22 and 13–14), and a shorter lower jaw (10.4–11.6% of standard length vs. 11.1–12.2%). *Sardinella pacifica* **sp. n.** is known only from the Philippines, whereas *S. fimbriata* is restricted to the Indian Ocean, although previously considered to be an Indo-West Pacific species, distributed from India to the Philippines.

Keywords

morphology, *Sardinella fimbriata*, Southeast Asia, taxonomy

Introduction

Sardinella Valenciennes, 1847, an Indo-Pacific and Atlantic genus of marine, brackish and/or fresh water sardines (Clupeidae), comprises 22 valid species (Whitehead 1985, Stern et al. 2016). Many species, including the endemic fresh water species *Sardinella tawilis* (Herre, 1927), occur in the Philippines (Fowler 1941, Rau and Rau 1980,

Whitehead 1985, Conlu 1986, Munroe et al. 1999, Willette et al. 2011a, b, Willette and Santos 2012, Stern et al. 2016, Hata 2017a, b), some being an important fisheries resource (locally named “tambam”, “tuloy”, and “tunsoy”) (Rau and Rau 1980, Conlu 1986). A recently described species, *Sardinella goni* Stern, Rinkevich & Goren, 2016 was based on specimens collected from Boracay Island, the Philippines.

During a revisionary study of *Sardinella*, 21 specimens of a clupeid fish from the Philippines were found to be characterized by a unique combination of scales with centrally discontinuous striae, a dark spot on the dorsal-fin origin, and low counts of lateral scales in the longitudinal series and pseudobranchial filaments. They are described herein as a new species of *Sardinella*.

Materials and methods

Counts and proportional measurements followed Hubbs and Lagler (1947) with additions as in Kimura et al. (2009). All measurements were made with digital calipers to the nearest 0.01 mm. Standard length is abbreviated as SL. Institutional codes follow Sabaj (2016).

Sardinella pacifica sp. n.

<http://zoobank.org/30675329-0FBF-45F3-ACF5-30D6C6669C39>

Figures 1–2, Table 1

Sardinella fimbriata: Fowler 1941: 609 (Bacon, Manilla and Aparri, Philippines); Chan 1965 (in part): 14 (Philippines); Rau and Rau 1980: 203 (Philippines); Whitehead 1985 (in part): 98, unnumbered fig. (Philippines); Conlu 1986: 45, fig. 20 (Alabat Island; Appari, Cagayan; Bacon, Sorsogon; Bauang, La Union; Calapan, Mindoro; Cavite, Cavite; Davao Gulf; Estancia, Iloilo; Malolos, Bulacan; Manila Bay; Margosatubig, Zamboanga; Nasugbu, Batangas; Ragay Gulf, Quezon; San Miguel Bay, Camarines Sur; Samar, Philippines); Munroe et al. 1999 (in part): 1814, unnumbered fig. (Philippines); Luceño et al. 2013: 30, fig. 2 (Butuan, Dipolog, and Pagadian, Mindanao Island, Philippines); Stern et al. 2016 (in part): 9, fig. 2 (b), fig. 4 (b) (Manilla, Philippines). (**non** Valenciennes)

Holotype. BMNH 1985.4.12.1, 105.1 mm SL, Manila Harbor, Manila Bay, Luzon Island, Philippines.

Paratypes. 20 specimens, 90.2–105.9 mm SL, all from the Philippines. BMNH 1960.4.7.52, 90.2 mm SL, Palawan Island; BMNH 1985.4.12.2, 98.7 mm SL, Manila Harbor, Manila Bay, Luzon Island; CAS 38365, 105.9 mm SL, Manila Bay, Luzon Island; CAS 51909, 96.5 mm SL, Manila Bay, Luzon Island; CAS 52501, 98.4 mm SL, Manila Bay, Luzon Island; CAS 59712, 100.3 mm SL, Bacon, Sorsogon, Luzon Island; CAS-SU 28568, 96.5 mm SL, Alabat Island; CAS-SU 28569, 101.3 mm SL,

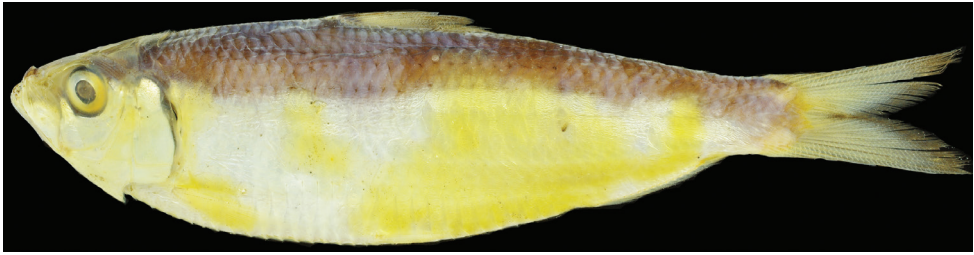


Figure 1. Holotype of *Sardinella pacifica* sp. n., BMNH 1985.4.12.1, 105.1 mm SL, Manila Bay, Luzon Island, Philippines.

Manila Bay, Luzon Island; CAS-SU 29920, 2 specimens, 97.6–103.3 mm SL, Manila Bay, Luzon Island; CAS-SU 32915, 2 specimens, 95.7–97.8 mm SL, Manila Bay, Luzon Island; KAUM–I. 125000, 95.9 mm SL, Manila Bay, Luzon Island; USNM 56232, 94.5 mm SL, USNM 56233, 92.2 mm SL, Bacon, Sorsogon, Luzon Island; USNM 72197, 92.9 mm SL, Manila, Luzon Island; USNM 177667, 2 specimens, 93.4–96.7 mm SL; USNM 403460, 95.9 mm SL, Navatos, Manila, Luzon Island; USNM 427789, 94.9 mm SL, Catbalogan, Samar Island, Visayas.

Diagnosis. A species of *Sardinella* with the following combination of characters: caudal fin with black posterior margin; lateral body scales with centrally discontinuous vertical striae, and few perforations and pores posteriorly; 38–41 (modally 38) lateral scales in longitudinal series; body scales deciduous; black spot on dorsal-fin origin; pelvic fin with one unbranched and seven branched rays; gill rakers 40–53 (43) in upper series on 1st gill arch, 71–84 (72) in lower series, 112–137 (118) in total; gill rakers 40–56 (42) in upper series on 2nd gill arch, 70–94 (79) in lower series, 112–148 (115) in total; gill rakers 37–52 (42) in upper series on 3rd gill arch, 57–75 (60) in lower series, 95–127 (99) in total; gill rakers 31–43 (35) in upper series on 4th gill arch, 44–63 (48) in lower, 78–106 (80) in total; gill rakers 30–43 (34) on hind face of 3rd gill arch; 17 or 18 (18) + 12 or 13 (13) = 29–31 (30) scutes on ventral edge of body; anal fin with 18–21 (20) rays; lower jaw rather short, 10.4–11.6% of SL.

Description. Counts and measurements, expressed as percentages of SL, are given in Table 1. Data for the holotype are presented first, followed by paratype data in parentheses. Body oblong, compressed, deepest at dorsal-fin origin. Dorsal profile of body elevated from snout tip to dorsal-fin origin, thereafter decreasing to uppermost point of caudal-fin base. Ventral profile of body curved downward from lower-jaw tip to pelvic-fin insertion, thereafter rounded to ventralmost point of caudal-fin base. Abdomen from isthmus to anus with 30 (29–31) scutes. Predorsal scutes absent. Anteriormost point of pectoral-fin insertion anterior to posteriormost point of opercle. Upper, posterior and ventral margins of pectoral fin nearly linear. Posterior tip of pectoral fin pointed. Pectoral-fin axillary scale present. Posteriormost dorsal-fin ray not filamentous. Anteriormost point of pelvic-fin insertion located directly below origin of 8th (7th–10th) dorsal-fin ray. Posterior tip of depressed pelvic fin reaching between a vertical through posterior end of dorsal-fin base and anus. Pelvic-fin axillary scale

Table 1. Counts and measurements of specimens of *Sardinella pacifica* sp. n. and *S. fimbriata*.

	<i>Sardinella pacifica</i> sp. n.			<i>Sardinella fimbriata</i>		
	Holotype	Paratypes	Modes	Lectotype	Non-types	Modes
	Manilla Bay, Philippines BMNH 1985.4.12.1	Philippines n = 20		Malabar, India MNHN 3227	Indian Ocean n = 16	
Standard length (SL; mm)	105.1	90.2–105.9		118.2	89.7–123.6	
Counts						
Dorsal-fin rays (unbranched)	4	4–5	4	4	4	4
Dorsal-fin rays (branched)	15	14–16	14	15	14–16	15
Anal-fin rays (unbranched)	3	3	3	3	3	3
Anal-fin rays (branched)	17	15–18	17	16	15–19	17
Pectoral-fin rays (unbranched)	1	1	1	1	1	1
Pectoral-fin rays (branched)	13	12–15	14	14	13–16	14
Pelvic-fin rays (unbranched)	1	1	1	1	1	1
Pelvic-fin rays (branched)	7	7	7	7	7	7
Caudal-fin rays (upper+ lower)	10 + 9	10 + 9	10 + 9	10 + 9	10 + 9	10 + 9
Gill rakers on 1st gill arch (upper)	44	40–53	43	49	40–49	49
Gill rakers on 1st gill arch (lower)	72	71–84	72	74	71–79	78
Gill rakers on 1st gill arch (total)	116	112–137	118	123	112–127	121
Gill rakers on 2nd gill arch (upper)	44	40–56	42	47	40–53	48
Gill rakers on 2nd gill arch (lower)	79	70–94	79	87	75–95	87
Gill rakers on 2nd gill arch (total)	123	112–148	115	134	115–146	123
Gill rakers on 3rd gill arch (upper)	43	37–52	42	49	37–50	45
Gill rakers on 3rd gill arch (lower)	61	57–75	60	69	60–82	75
Gill rakers on 3rd gill arch (total)	104	95–127	99	118	100–131	122
Gill rakers on 4th gill arch (upper)	35	31–43	35	39	30–40	36
Gill rakers on 4th gill arch (lower)	49	44–63	48	51	43–53	48
Gill rakers on 4th gill arch (total)	84	78–106	80	90	74–93	90
Gill rakers on posterior face of 3rd gill arch	32	30–43	34	36	31–39	36
Prepelvic scutes	18	17–18	18	18	17–18	18
Postpelvic scutes	12	12–13	13	14	13–14	14
Total scutes	30	29–31	30	32	31–32	32
Lateral scales in longitudinal series	41	38–41	38	45	44–46	45
Pseudobranchial filaments	18	14–19	18	21	19–22	21
Measurements (%SL)			Means			Means
Head Length	24.9	23.1–26.8	25.3	26.5	25.0–28.5	26.5
Body depth	31.5	28.3–36.9	31.3	33.1	28.8–32.3	31.0
Pre-dorsal-fin length	42.3	41.9–46.1	44.3	44.9	43.9–46.7	45.2
Snout tip to pectoral-fin insertion	25.1	24.2–27.9	26.3	27.9	25.2–27.9	26.8
Snout tip to pelvic-fin insertion	51.4	48.3–55.1	51.7	53.4	50.5–53.1	51.7
Pre-anal-fin length	76.4	72.9–79.3	77.3	77.9	75.2–77.7	76.7
Dorsal-fin base length	16.1	13.9–16.5	15.2	13.4	13.4–16.6	14.9
Anal-fin base length	15.7	13.9–17.6	16.0	16.0	13.7–17.5	16.1
Caudal-peduncle length	9.5	7.7–10.4	9.0	9.1	8.1–10.2	9.4
Caudal-peduncle depth	9.5	9.1–11.1	10.0	10.5	9.5–10.0	9.8
Dorsal-fin origin to pectoral-fin insertion	31.8	28.4–34.2	32.1	33.9	30.6–34.1	32.1
Dorsal-fin origin to pelvic-fin insertion	30.5	27.4–35.9	30.5	32.3	28.0–31.4	30.1
Dorsal-fin origin to anal-fin origin	42.1	39.9–45.0	43.0	43.0	39.5–43.5	41.4
Pectoral-fin insertion to pelvic-fin insertion	27.9	23.5–9.5	26.7	27.0	25.0–27.4	25.9
Pelvic-fin insertion to anal-fin origin	30.5	26.1–31.8	28.8	27.7	26.1–29.7	27.4
Pectoral-fin length	broken	18.2–20.8	19.6	18.8	17.4–19.7	18.7
Pelvic-fin length	10.7	10.3–11.9	11.2	11.0	9.5–11.6	10.9
Interorbital width	4.2	4.0–5.0	4.5	4.6	3.8–5.0	4.5
Postorbital length	12.4	10.4–13.7	12.0	12.6	11.2–13.9	12.8
Upper-jaw length	9.6	9.3–10.9	10.0	10.7	9.5–11.0	10.4
Mandible length	10.7	10.4–11.6	11.0	11.6	11.1–12.2	11.5
1st unbranched dorsal-fin ray length	1.5	1.1–3.0	1.8	0.9	1.4–3.5	2.1

	<i>Sardinella pacifica</i> sp. n.			<i>Sardinella fimbriata</i>		
	Holotype	Paratypes		Lectotype	Non-types	
	Manilla Bay, Philippines BMNH 1985.4.12.1	Philippines n = 20	Means	Malabar, India MNHN 3227	Indian Ocean n = 16	Means
2nd unbranched dorsal-fin ray length	7.2	2.5–9.0	5.2	2.7	3.5–7.5	5.1
3rd unbranched dorsal-fin ray length	11.8	6.2–13.7	9.5	7.6	7.4–12.5	9.4
1st unbranched anal-fin ray length	1.0	0.8–1.9	1.3	broken	0.6–1.8	1.3
2nd unbranched anal-fin ray length	broken	2.3–5.3	3.6	broken	1.9–3.9	2.8
3rd unbranched anal-fin ray length	broken	4.9–6.1	5.6	5.7	4.6–6.5	5.5
1st pectoral-fin ray length	broken	16.9–19.9	18.5	broken	16.5–19.4	18.0
1st pelvic-fin ray length	10.6	10.3–11.9	11.1	11.0	10.4–11.6	10.9

present. Anal-fin origin posterior to vertical through posteriormost point of dorsal-fin base. Two posteriormost anal-fin rays enlarged. Caudal fin forked. Posterior tips of caudal-fin lobes pointed. Anus on ventral midline, slightly anterior to anal-fin origin, posterior to midpoint of body. Scales cycloid, thin, deciduous, except for robust ventral scutes. Scales on lateral body surface with several centrally discontinuous vertical striae, few perforations and pores posteriorly (Fig. 2). Bases of dorsal and anal fins with low scaly sheaths. Predorsal scales paired. No elongate, wing-like scales present beneath normal paired scales. No scales on head and fins, except for a broad triangular sheath of scales on caudal fin. Mouth terminal, small, posterior tip of maxilla not reaching vertical through anterior margin of iris. Premaxilla and hypomaxilla without teeth. Ventral margin of maxilla toothed. Lower jaw with several conical teeth anteriorly. Posterior ramus of lower jaw elevated. Second supramaxilla symmetrical. Orbit elliptical, eye and iris round. Eyes covered with adipose eyelid posteriorly. Interorbital space flat. Nostrils close to each other, anterior to orbit. Eight (8–10) on top of head. No lateral line. Gill rakers long, slender, with small asperities on anterior surface. Pseudobranchial filaments present. Gill opening with two fleshy outgrowths on posterior margin and a large papilla on ventral margin. Posterior margins of preopercle and opercle smooth.

Color of preserved specimens. Body dark brown dorsally, elsewhere yellowish silver. Black spot on dorsal-fin origin. Melanophores scattered on upper part of dorsal fin and first pectoral-fin ray. Posterior margin of caudal fin dark. Fresh coloration shown in Luceño et al. (2013) (as *S. fimbriata*).

Distribution. Currently known only from the Philippines.

Etymology. The specific name *pacifica* (in reference to the Pacific Ocean) is given to distinguish the species from *S. fimbriata*, with which it had been confused, and which is now considered to be restricted to the Indian Ocean.

Remarks. The new species is assignable to the genus *Sardinella*, defined by Whitehead (1985) and Munroe et al. (1999), due to its compressed body, abdomen covered with prominently keeled scutes, paired predorsal scales, a symmetrical second supramaxilla, toothless hypo-maxilla, two posteriormost anal-fin rays enlarged, the dorsal fin without filamentous rays, and two fleshy outgrowths on the hind margin of the gill opening. It most closely resembles *Sardinella fimbriata* (Valenciennes, 1847) (Fig. 3), sharing centrally discontinuous striae on the lateral body scales, a dark spot on the dor-



Figure 2. Photograph of a stained scale, collected from mid-body below the dorsal fin, of *Sardinella pacifica* sp. n. (BMNH 1985.4.12.1, 105.1 mm SL, Manila Bay, Luzon Island, Philippines).



Figure 3. Lectotype of *Sardinella fimbriata*, MNHN 3227, 118.2 mm SL, Malabar, India.

sal-fin origin, more than 70 lower gill rakers on the first gill arch, eight pelvic-fin rays, 15–18 branched anal-fin rays, and 17 or 18 prepelvic scutes (Whitehead 1985, Munroe et al. 1999, Stern et al. 2016). However, *S. pacifica* can be distinguished from the latter by lower counts of lateral scales in the longitudinal series (38–41 vs. 44–46 in *S. fimbriata*; Table 1), pseudobranchial filaments (14–19 vs. 19–22; Table 1; Fig. 4A) and postpelvic scutes (12 or 13 vs. 13 or 14; Table 1), and a shorter lower jaw (10.4–11.6% SL vs. 11.1–12.2%; Table 1; Fig. 4B). Moreover, the deciduous body scales of the new species are distinctively diagnostic, the body scales of *S. fimbriata* being non-deciduous. Although *S. fimbriata* has been regarded as an Indo-West Pacific species, distributed from India to the Philippines (Whitehead 1985, Munroe et al. 1999, Stern et al. 2016), no Pacific region specimens of *S. fimbriata* appear to have been collected (see comparative materials), and the species is judged herein to be an Indian Ocean endemic.

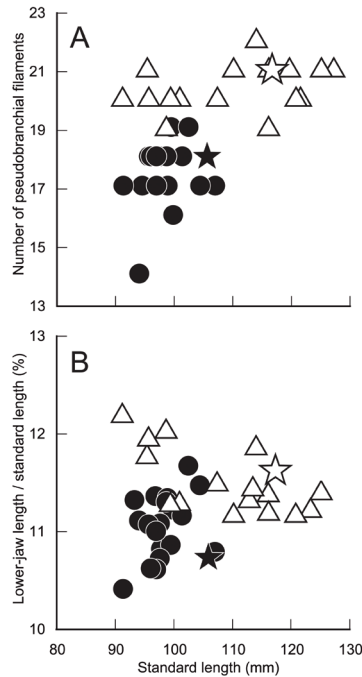


Figure 4. Relationships of (A) pseudobranchial filament numbers, and (B) lower-jaw length (as % of standard length) to SL in *Sardinella pacifica* sp. n. [solid circles (solid star = holotype)] and *S. fimbriata* [open triangles (open star = lectotype)]

Comparative material examined. *Sardinella fimbriata* (Valenciennes, 1847) (17 specimens, 89.7–123.6 mm SL): BMNH 1889.2.1.1778, 112.0 mm SL, Madras, India; BMNH 1889.2.1.1915–1916, 1 of 2 specimens, 97.9 mm SL, Orissa, India; BMNH 1889.2.1.1917, 99.5 mm SL, Akyab, Burma; CAS 41433, 2 specimens, 89.7–93.9 mm SL, Calicut, India; CAS 41434, 2 specimens, 94.2–97.2 mm SL, Ernakulam, Cochin, India; CAS 41435, 119.3 mm SL, Madras, India; MNHN 3227, lectotype of *Spratella fimbriata*, 118.2 mm SL, Malabar, India; USNM 276446, 121.8 mm SL, Cochin, Kerala, India; USNM 276447, 105.6 mm SL, Kovalam, Trivandrum, India; USNM 276449, 2 specimens, 108.7–114.6 mm SL, Vizhinam, Trivandrum, Kerala, India; USNM 276450, 4 specimens, 111.4–123.6 mm SL, Calicut, Kerala, India.

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A check list and population trends of invasive amphibians and reptiles in Taiwan

Ko-Huan Lee^{1,2}, Tien-Hsi Chen³, Gaus Shang⁴, Simon Clulow²,
Yi-Ju Yang⁵, Si-Min Lin¹

1 School of Life Science, National Taiwan Normal University, Taipei 116, Taiwan **2** Department of Biological Sciences, Macquarie University, Sydney, NSW, Australia **3** Institute of Wildlife Conservation, National Pingtung University of Science and Technology, Pingtung 912, Taiwan **4** Department of Biotechnology, Ming Chuan University, Taoyuan 333, Taiwan **5** Department of Natural Resources and Environmental Studies, National Dong Hwa University, Hualien 974, Taiwan

Corresponding authors: Yi-Ju Yang (treefrog@gms.ndhu.edu.tw); Si-Min Lin (lizard.dna@gmail.com)

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Abstract

Invasive species have impacted biodiversity all around the world. Among various ecosystems, islands are most vulnerable to these impacts due to their high ratio of endemism, highly specialized adaptation, and isolated and unique fauna. As with other subtropical islands, Taiwan faces Conant risk of biological invasions and is currently ranked as one of the countries most affected by invasive amphibians and reptiles. In this paper, a comprehensive checklist of all known exotic amphibians and reptiles is provided, including twelve species which have successfully colonized Taiwan and six species with a controversial status. We provide an update on the knowledge of all these species including their distribution, colonization history, threats to native animals, and population trends based on literature records, fauna surveys, and data collected during invasive species eradication and control programs. A list of species with high invasive potentials is also provided. This study reports, for the first time, a comprehensive survey of invasive herpetofauna in Taiwan, which should provide a valuable reference to other regions which might suffer from similar invasion risk.

Keywords

Alien species, CITES, fauna checklist, international trade, island biogeography, IUCN

Introduction

Invasive species have been listed as one of the major threats to global biodiversity (Charles and Dukes 2008, Bellard et al. 2016, Early et al. 2016). The negative impacts of invasive species include predation, competition, hybridization, and introduction of exotic pathogens (Mooney and Cleland 2001, Gurevitch and Padilla 2004, Hulme 2014, Doherty et al. 2016). These in turn have contributed to the decrease of global diversity either by directly eliminating native species (decrease of alpha diversity), or by indirectly reducing the local uniqueness because of homogenization (decrease of beta diversity). Among various ecosystems, islands are especially sensitive to the impacts of invasive species (O'Dowd et al. 2003, Sax and Gaines 2008). Insular species are usually kept isolated from their mainland relatives, adapt to specific niches on the islands, and represent a high ratio of endemism by being distributed in a comparatively narrow range. These species are considered at greatest risk from biological invasions, and explains in part why a majority of human-induced extinction has occurred on islands during the last several centuries (Fritts and Rodda 1998, Blackburn et al. 2004, Wyatt et al. 2008).

Taiwan is a medium-sized island located approximately 130 km east from continental Asia. Located at the border between the Palearctic and Indomalaya regions, fauna on this island consists of evolutionary lineages from both of these biogeographic regions (Toda et al. 1998, Shih et al. 2006, Yu et al. 2014, Tseng et al. 2018). Due to low oversea dispersal ability, herpetofauna represents the highest proportion of endemism among terrestrial vertebrates in Taiwan (Zhang-Jian 2002). Excluding marine species (sea turtles and sea snakes), there are 37 amphibians and 85 reptiles native to the island (Shang et al. 2009), with new species still being discovered in recent years (You et al. 2015, Wu et al. 2016, Wang et al. 2017). Among these, five salamanders (100%), 14 frogs (44%), 18 lizards (55%), and 14 snakes (29%) are endemic to the island (several of these are endemic subspecies). In addition to the high levels of endemism, amphibians and reptiles in Taiwan are also characterized by their remarkable fine-scaled differentiation. Phylogenetic studies have indicated several *in situ* speciation cases within the limited range of this island, while there are several cases of restricted geographic distribution between sibling taxa (Lai and Lue 2008, Lin et al. 2012, Tseng et al. 2015). Most endemic species on the island occupy only a small distribution, while the contact zone(s) between sibling species provide a valuable laboratory for evolutionary studies (Tseng et al. 2014, Wang et al. 2017).

Like other islands, Taiwan has suffered from biological invasions. Harbors in Taiwan have long played the role of international transfer stations for trade among adjacent regions; a considerable proportion of trade materials includes agricultural products, fishery products, garden plants, live animals, and wildlife products. Furthermore, keeping amphibians and reptiles as pets has become more popular in recent years. Based on a global review of invasive herpetofauna around the world by Capinha et al. (2017), it was estimated there are now 10 exotic species of herpetofauna in Taiwan, ranking it as the 10th most invaded country by herpetofauna in the world. However, more recent

surveys by the authors of this paper have identified several other species of invasive herpetofauna, thus creating a need for a more up to date review of the invasive herpetofauna present in Taiwan and the threats that these species pose. Moreover, we also aim to improve the current status that a large proportion of information of these invasive species are based merely on folk information, and has never been formally published.

In this paper, we provide an up to date and detailed checklist of exotic amphibian and reptile species which have successfully colonized Taiwan. For each species, we collected information on their colonization history, the potential threats they pose to local species and ecosystems, eradication and control attempts conducted by scientists, and some new data collected during these attempts. Finally, we made some broad assumptions on their future trends based upon observations and data collected in field. We hope this will provide a valuable reference for conservation managers both in Taiwan and in other regions that face similar invasion risks.

Materials and methods

We collected all available information on invasive amphibians and reptiles in Taiwan (names and authorities provided in Table 1), including a thorough search of the literature, and data collected during fauna surveys from several ongoing invasive species eradications, control, and research programs. Information of species listed below was based on some of the authors' research outcomes: *Polypedates megacephalus*, *Trachemys scripta elegans*, *Physignathus cocincinus*, *Chamaeleo calypttratus*, *Iguana iguana*, *Anolis sagrei*, *Gekko gecko*, and *Gecko monarchus*. Four other known invasive species were not studied directly by us; instead we collected available information since 1980s. These species include *Kaloula pulchra*, *Fejervarya cancrivora*, *Hemidactylus brookii*, and *Eutropis multifasciata*.

In addition to the above commonly-recognized invasive species, recent studies have provided evidence to suggest that several long-occurring reptile species traditionally considered native to Taiwan may have indeed been relatively recent invaders. These include *Mauremys reevesii*, *Hemidactylus frenatus*, *Lepidodactylus lugubris*, *Hemiphyllodactylus typus*, and *Indotyphlops braminus*. The American Bullfrog *Lithobates catesbeianus*, on the other hand, was traditionally thought to be an established invasive species, but there is considerable doubt as to whether they are actually self-sustaining or whether they are simply continually released. Collectively, these species are listed as having a "controversial status", with relevant discussion below.

Finally, Taiwan is frequently exposed to accidental or intentional release of exotic animals that are not yet considered established and invasive. A large proportion of these animals constitute escaped or released pets. Although frequently reported by animal rescue centers, these species have not yet established breeding populations and are thus not considered invasive. We have categorized these species as "high-risk" that have a high likelihood of establishing as invasive in the future (names and authorities in Table 2), and have made brief comments on these in the last section.

Table 1. A list of invasive amphibians and reptiles in Taiwan.

Species	1 st record	Possible origin	Removal fund source	Trend
Amphibians				
<i>Kaloula pulchra</i> Gray, 1831; Banded Bullfrog	1997	Timber trades (?)	Government + NGO ¹	PE
<i>Fejervarya cancrivora</i> (Gravenhorst, 1829); Mangrove Frog	2005	Imported fish fry	None	PE
<i>Polypedates megacephalus</i> Hallowell, 1861; Spot-legged Tree Frog	2006	Horticultural plants	Government + NGO	PE
Turtles				
<i>Trachemys scripta elegans</i> (Wied, 1838); Red-eared Slider	N/A	Intentional release	None	PE
Squamata				
<i>Physignathus cocincinus</i> Cuvier, 1829; Chinese Water Dragon	2010	Intentional release	Government + private	PE
<i>Chamaeleo calytratus</i> Duméril and Bibron, 1851; Veiled Chameleon	2011	Intentional release	Private people	PP
<i>Iguana iguana</i> (Linnaeus, 1758); Common Green Iguana	2004	Intentional release	Government	PE
<i>Anolis sagrei</i> Dumeril and Bibron, 1837; Brown Anole	2000	Horticultural plants	Government + NGO	PE
<i>Gekko gekko</i> (Linnaeus 1758); Tokay Gecko	2008	Intentional release (?)	Private people	PP
<i>Gecko monachus</i> (Schlegel, 1836); Spotted House Gecko	2009	International trades	Government	PE
<i>Hemidactylus brookii</i> Gray, 1845; Brook's House Gecko	2018	International trades	None	PE
<i>Eutropis multifasciata</i> (Kuhl, 1820); Many-lined Sun Skink	1992	Timber trades (?)	Government ²	PE
Species with a controversial status				
<i>Lithobates catesbeianus</i> (Shaw, 1802); American Bullfrog	N/A	Intentional release	None	?
<i>Mauremys reevesii</i> (Gray, 1831); Reeves' Turtle	1934	Intentional release	None	PD
<i>Hemidactylus frenatus</i> Dumeril and Bibron, 1836; Common House Gecko	1885	Unknown	None	PE
<i>Lepidodactylus lugubris</i> (Dumeril and Bibron, 1836); Morning Gecko	1984	Unknown	None	PP
<i>Hemiphyllodactylus typus</i> Bleeker, 1860; Indopacific Tree Gecko	1985	Unknown	None	PP
<i>Indotyphlops braminus</i> (Daudin, 1803); Brahminy Blindsnake	?	Unknown	None	PP

PE: population expansion; PP: population persistency; PD: population decline

¹ – The governmental support has ceased for several years.

² – Governmental support for removal only on Green Island.

Results and discussion

Based on our review, we determined that there is a total of three amphibian and nine reptile species that have established stable, invasive populations in Taiwan (Table 1). Seven of these have been funded for eradication programs, of which one (*K. pulchra*) was ceased in recent years, and another (*E. multifasciata*) conducted only for the population on Green Island. *Chamaeleo calytratus* and *Gekko gekko* were captured opportunistically by students, herpers, or pet keepers; the remaining species have never received official intervention actions.

We determined that one frog (*L. catesbeianus*), one turtle (*M. reevesii*), and four squamates should be listed as having a controversial invasion status. In the first case, there is no confirmed evidence that *L. catesbeianus* has established a stable breeding population

Table 2. A list of species with released individuals being frequently discovered, or with high invasive potential.

Species	Frequency in pet trades ¹	Records of escaped individuals ²
Amphibians		
<i>Cynops orientalis</i> (David, 1873); Oriental Fire-bellied Newt	Very high	Medium
<i>Rhinella marina</i> (Linnaeus, 1758); Cane Toad, Marine Toad	Medium	Low
<i>Polypedates leucomystax</i> (Gravenhorst, 1829); White-lipped Treefrog	Low	Low
Squamata		
<i>Anolis carolinensis</i> Voigt, 1832; Green Anole	Low	Low
<i>Salvator merianae</i> (Dumeril & Bibron, 1839); Black-and-white Tegu	High	High
<i>Varanus niloticus</i> (Linnaeus, 1766); Nile Monitor	Medium	Medium
<i>Varanus salvator</i> (Laurenti, 1768); Common Water Monitor	Medium	Medium
<i>Malayopython reticulatus</i> (Schneider, 1801); Reticulated Python	Medium	Medium
<i>Python bivittatus</i> Kuhl, 1820; Burmese Python ³	Medium	Medium
Turtles		
<i>Macrochelys temminckii</i> Troost, 1835; Alligator Snapping Turtle	High	High
<i>Chelydra serpentina</i> (Linnaeus, 1758); Common Snapping Turtles	High	High
<i>Pseudemys concinna</i> (Le Conte, 1830); Eastern River Cooter	Very high	Very high
<i>Trachemys scripta scripta</i> (Schoepff, 1792); Yellow-bellied Slider	Very high	Very high
Crocodilians		
<i>Caiman crocodilus</i> (Linnaeus 1758); Spectacled Caiman	Medium	Medium

¹ – Definition of frequency in pet trades: very high: > 10 individuals in most pet stores; high: < 10 individuals in most pet stores; medium: < 10 in a low proportion of pet stores; low: occasionally available or none.

² – Definition of escaped records: very high: frequently found in the wild; high: more than 5 records in urban or natural settings each year; medium: 1 – 5 records in urban or natural settings each year; low: occasional records or none.

³ – Population of *Python bivittatus* is native only in Kinmen Archipelago; individuals found in Taiwan are usually escaped pets.

in Taiwan. In contrast, *M. reevesii* and *H. frenatus* should be revised to be considered as introduced species due to new lines of evidence based on genetic data and historical records (not from this study), both of which are discussed below. The three parthenogenetic squamates, *L. lugubris*, *H. typus*, and *I. braminus*, are considered invasive in Taiwan according to some authors (Ota et al. 2004, Kraus 2009). These species suffer from data deficiency and require further studies to conclusively confirm their status in Taiwan.

In terms of population trends, *M. reevesii* seems to have experienced dramatic population declines in the late 20th century and has become near-extinct, although the reasons for this are unknown. Several medium- to large-sized lizards (e.g., *C. calypttratus* and *G. gecko*) were successfully, albeit temporarily controlled by students and pet keepers, primarily due to their market value, which led to at least a temporary reduction in the population size. One invasive frog (*F. cancrivora*) appears to be stable in population size, while others have continued to increase in population size over time with no signs of plateauing.

The 14 species summarized in Table 2, considered high-risk to become invasive in Taiwan, are either common in pet shops, frequently escape and are found in near-urban regions, or experience high levels of accidental invasion by international traders. These species are considered likely to invade Taiwan if no biosecurity restriction policy is put in place in the near future.

In the following sections, we discuss the detailed information from all the invasive species in these lists.

***Kaloula pulchra* (Gray, 1831)**

Natural distribution. As a widely distributed species in South and Southeastern Asia, the west boarder of this medium-sized microhylid frog (Fig. 1) is India and Bangladesh, and it is widely distributed in Myanmar, Laos, Thailand, Malaysia, Singapore, certain areas of Indonesia, Cambodia, Vietnam, and south China, including Hong Kong and Macau (Vassilieva et al. 2016). It was introduced to Luzon, Philippines, probably through international pet trades (Diesmos et al. 2006). It was classified as “Least Concern” by IUCN Red List in 2004. Due to its wide distribution and tolerance of many kinds of habitats, it is not listed as threatened under any other legislative lists.

Colonization history. This species was first reported in 1997 by Yan-Hung Pan, from a military base in Linyuan District, Kaohsiung City (point 1 in Fig. 1A). In the following year, six specimens were captured at the same locality and sent to National Taiwan University for further identification. Based on morphology, one of us, Dr. Yi-Ju Yang, confirmed that this was the first record of *K. pulchra* in Taiwan. From the analysis of their mitochondrial genes, this species in Taiwan does not seem to have originated from nearby China (Lin 2007) and the origin of this frog remains unknown. Linyuan District is adjacent to Kaohsiung Harbor with many wood processing plants around this region and it is believed the species have entered via this route, as has been found to be the case in New Zealand (Gill et al. 2001).

The distribution and population size of this frog remained limited until the early 21st century. The distribution started to increase after a significant flood in August 2009, which spread the frog to more lowland localities. In an investigation by Hou 2011, the species was found to have a disjunct distribution in Tainan, Kaohsiung and Pingtung Counties. However, these isolated populations gradually expanded and merged, while newly established populations have occurred in Yunlin County and Kenting National park (point 2 in Fig. 1A); these two places represent the northern and southern-most boundaries of their current distribution up until 2017. New geographically isolated records of this frog were steadily being reported, such as Mudan Township in Pingtung County (Meng-Hsien Chuang, pers. comm.). To date, the hot spots for this species include Tainan (Gueiren, Guanmiao, and Longci), Kaoshiung (Lujhu, Tianliao, Tzukuan, Ciaotou, Daliao, Linyuan, and Kaohsiung Metropolitan Park), and Pingtung (Neipu, Wanluan, Shinpi, and Kenting National Park) (Hou 2011, Chang 2012, Chen 2015).

Threats to native species and ecosystems. This species is usually abundant in invaded regions, but its threat to local fauna is still obscure. In Taiwan, *K. pulchra* usually shares similar food items with *Duttaphrynus melanostictus* (Bufonidae) which preys heavily upon ants and other litter insects. Nevertheless, there is not yet clear evidence that the former represents strong competition with the latter (Liang 2005). Another consideration is that invasive poisonous amphibians can harm local naïve predators through lethal toxic ingestion (Fig. 1B; Burnett 1997, Letnic et al. 2008, Shine 2010). While the effect of their toxin on native predators remains unstudied,

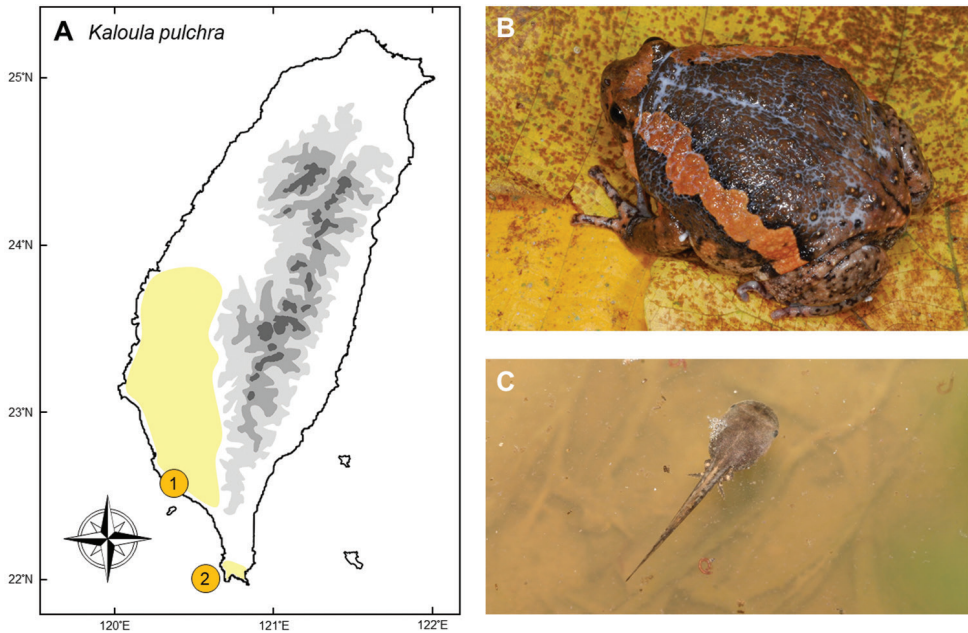


Figure 1. **A** The occurrence of *Kaloula pulchra* was first discovered in Kaohsiung (1), and later expanded northward to Yunlin, and southward to a disjunct location in Kenting (2) **B** the skin of this medium- to large-sized microhylid can secrete toxins **C** their tadpoles are commonly found in the invasive regions. Photographed by Gaus Shang (**B**) and Yin-Hsun Yang (**C**).

there are several toad-eating snakes that could potentially prey on *K. pulchra*, such as *Dinodon rufozonatum*, *Macropisthodon rudis*, *Rhabdophis formosanus*, and *Naja atra* (Karsen et al. 1998; Shang et al. 2009). Experiments on captive individuals of these snakes showed that at least *N. atra* can successfully consume it. A recent record in Tainan showed that *K. pulchra* may be sympatrically distributed with the critically endangered treefrog *Rhacophorus arvalis* (Rhacophoridae). The impact of *K. pulchra* on *R. arvalis*, which has an extremely narrow distribution, requires careful monitoring.

Current status and trends. The invasion dynamics of *K. pulchra* represented a typical trend of an invasive species: it remained in small numbers for quite a long period, and only started to expand after a “lag time” between initial colonization and the onset of rapid population growth and range expansion (e.g., Kowarik 1995, Sakai et al. 2001). Since the flood in 2009, its distribution and population size gradually increased. Although the speed of spread has been slow, its expansion continues to the present day. Because the species burrows under the soil (especially in the dry season), evaluation and removal of this long-lived frog is difficult. Typhoons and floods, as well as occasional release by pet keepers (Lin 2007), further facilitate their dispersal. The species has low mobility and thus eliminating it might be possible during the early stages of invasion; yet this phase seems to have passed in Taiwan and successful eradication seems unlikely.

The government initiated several programs to evaluate the distribution and population size of this species since 2005, but the programs did not persist (Hou 2011, Chang 2012). Although local government and nongovernment organizations have supported volunteers to remove this species, most of the captured individuals were adults and the number was too small to effectively decrease its population size (Old Bridge Association of Kaohsiung 2016). According to Hou 2011, at least 70% of eggs (tadpoles) and 30% of frogs must be removed in order to effectively decrease the population size. The ability to hibernate in mud and with a fair tolerance of overwintering in Taiwan, this species will likely gradually disperse northward (Chang 2012).

***Fejervarya cancrivora* (Gravenhorst, 1829)**

Natural distribution. Inhabiting the coasts and mangroves across south Asia, this robust microglossid frog (Fig. 2) is known for its tolerance to brackish water in both larval and adult stages. The distribution ranges from the Philippines to Indonesia, as far east as Flores Island (Grismer 2011a). It also occurs in south China, Thailand, Peninsular Malaysia and west to India (Orissa and Pondicherry) (Grismer 2011a, Satheeshkumar 2011). This species has also been introduced to New Guinea and Guam (Menzies 1996, Christy et al. 2007a). The IUCN assessed this species as Least Concern, and it is not listed under CITES.

Colonization history. This species was first listed as present in Taiwan by Johnson TF Chen in his first (Chen 1956) and second (Chen 1969) editions of “A synopsis of the vertebrates of Taiwan”. However, no voucher specimen was mentioned in Chen’s records; and no further records were mentioned since Chen’s book. Based on the description in the books, it might have been a misidentification from the morphologically similar native species *Hoplobatrachus rugulosus*.

In June 2005, this frog was once again discovered by Mr Jia-Hui Lin, a teacher of Renhe primary school, Pingtung County. It was preliminarily identified by Dr Yi-Ju Yang and Cheng-En Li by photograph. Several specimens were later collected in July of the same year, and mating pairs and tadpoles were discovered in October. *Fejervarya cancrivora* was thus confirmed as a breeding population in southern Taiwan. This frog now has a restricted distribution in Taiwan to the river mouth of Donggang Stream and Linbian Stream, belonging to Donggang, Linbian, Jiadong, and Fangliao townships (point 1 in Fig. 2A).

Molecular analyses have shown that this population is closely related to the populations from Borneo, Sumatra, and the Malay Peninsula, but distantly related to adjacent populations in China and the Philippines (Kurniawan et al. 2010). Therefore, this population was confirmed to be exotic. Borneo, Sumatra, and the Malay Peninsula are famous for their aquaculture; the origin of this frog is considered likely to have been introduced with imported fry.

Threats to native species and ecosystems. *Fejervarya cancrivora* normally utilizes brackish water, where almost no other amphibians exist. In Taiwan, they utilize fish

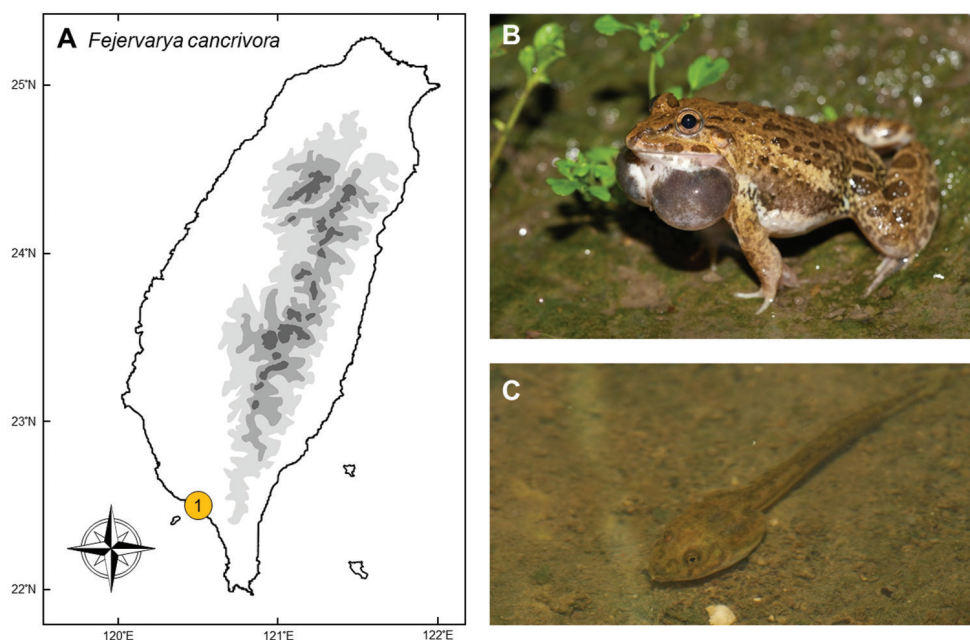


Figure 2. **A** Distribution of *Fejervarya cancrivora* is restricted to blackish water and fish ponds in Donggang, Linbian, Jiadong, and Fangliao townships of Pingtung County (1) **B** a male frog delivering the breeding call **C** a tadpole of *F. cancrivora*. Photographed by Yin-Hsun Yang.

farms, mangroves, and occasionally occur in orchards of wax apple, where local people use salty water to enhance the fertility of the plants. In inland areas, they sometimes occur in sympatry with native species *Fejervarya limnocharis*, *Microhyla fissipes*, and *Duttaphrynus melanostictus*, but the population is not dominant. Owing to the low to medium abundance of the frog and the lack of relevant research, there is no evidence for competition between *F. cancrivora* and native species, nor for the effects on the native food-web through predation as well as by being preyed.

Current status and trends. This species is currently found only in Donggang, Linbian, Jiadong, and Fangliao townships of Pingtung County, and also in the mangroves of Dapeng Bay. The population is limited both in abundance and range, with no prominent sign of fast continuing spread. There has not been a proposal to conduct removal or research on this species.

Polypedates megacephalus Hallowell, 1861

Natural distribution. This medium-sized Old-world treefrog (Rhacophoridae, Fig. 3) is widespread in India, Bangladesh, Myanmar, Thailand, Laos, Cambodia, Vietnam and southern China, including Hainan Island (Fei et al. 2012, Vassilieva et al. 2016).

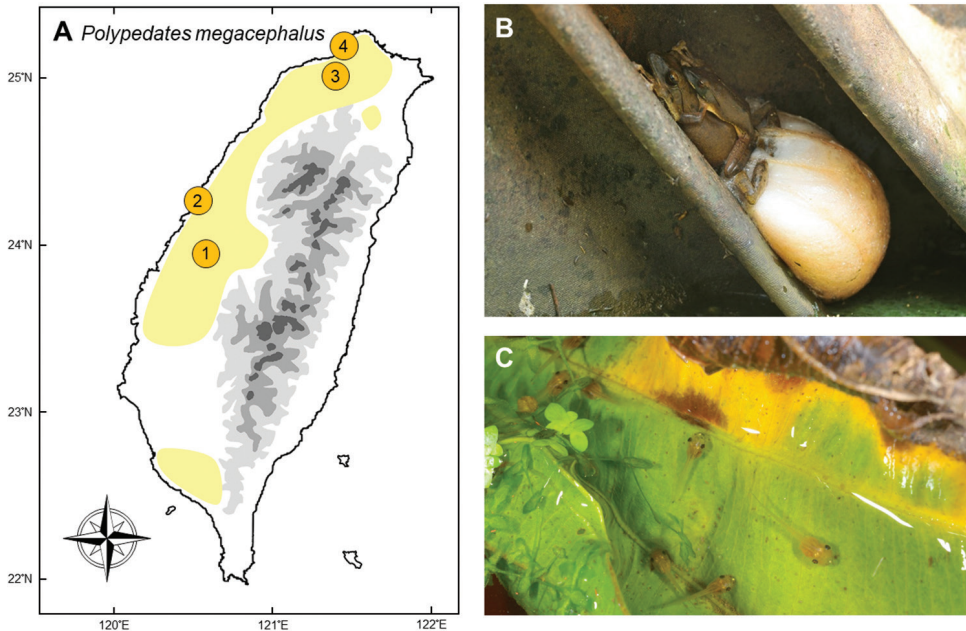


Figure 3. A Invasion of *Polypedates megacephalus* started in central Taiwan (Tienwei (1) and Wuchi (2)), and spread quickly by island hopping from habitat to habitat forward to northern Taiwan (Yingge (3) and Bali (4)) **B** a mating pair of adults with their foam nest **C** a small group of *P. megacephalus* tadpoles. Photographed by Yu-Jen Liang (**B**) and Gaus Shang (**C**).

It was reported to have invaded Guam from China through shipments (Christy et al. 2007a, Christy et al. 2007b). However, other brownish *Polypedates* spp. in East and Southeast Asia, such as *P. leucomystax* and *P. braueri*, form a group of morphologically similar species complex, which has caused taxonomic confusion in past decades. Therefore, the precise definition of members within this group needs to be clarified and might cause misidentifications (Kuraishi et al. 2013). The IUCN lists this species as Least Concern, and there are no trade restrictions.

Colonization history. This species was first recorded by a citizen of Wuchi, Taichung City who accidentally brought a group of tadpoles home with aquatic plants from Tienwei, Changhua in 2006 (point 1 Fig. 3A). Upon metamorphosis, he realized this species might have not been recorded in Taiwan (Yang and Gong 2014). By 2010, there were established populations in Taichung (point 2), Taoyuan (point 3) and New Taipei City (point 4). The disjunct distribution implied that human-mediated dispersal had occurred, rather than motive expansion. It was suspected that this species was imported with aquatic plants, and was most likely to disperse through the nursery trade (Zhang 2008).

When this species was first found in 2006, it could only be found in Changhua and Taichung. During the first several years, this species formed a disjunct distribution in northern (Taipei and Taoyuan) and central (Taichung and Changhua) Taiwan. It expanded progressively to nearby regions, such as Keelung, Yilan, Hsinchu, Miaoli,

Nantou, Yunlin, and Pingtung (Yang and Gong 2014, Chen 2015). In 2013, this species was found in one third of the surveyed areas (Yang et al. 2014); and expanded to 109 of 148 sampling sites (> 70%) in 2017 (Yang and Chen 2017).

Threats to native species and ecosystems. *Polypedates megacephalus* preys primarily on small insects, and sometimes small vertebrates such as *Gekko hokouensis*, *Diploderma swinhonis*, and *Microhyla fissipes* (Chen 2014). The most serious threat to native fauna might be resource competition with local anura, especially *P. braueri* which occupies a similar niche. Compared to *P. braueri*, *P. megacephalus* is larger in body size and has a larger clutch size (Wu et al. 2010). Strong competitive exclusion has been documented when *P. megacephalus* invades into the habitat of *P. braueri*; among a number of localities which are apparently suitable to both species, only the former can now be found (Yang and Chen 2016, 2017).

Current status and trends. This species is still expanding rapidly, with individuals being able to migrate up to 744 meters in a single day (Chang 2016). In 2017, Yang and Chen (2017), reported that the species had invaded 13 of the 22 counties surveyed in 1,085 localities; most of which are disturbed areas such as parks and school campuses. They reported 13,225 individuals, making the species one of the most abundant amphibians on the island.

Monitoring and removal of this species began in 2011, supported by the Forestry Bureau. Hundreds of individuals were removed by volunteers every year from at least four hotspots: Bali (point 4 in Fig. 3A), Yingge (point 3), Taichung Metropolitan Park, and Tienwei (point 1) between 2012 and 2017 (Yang and Chen 2017). Removal projects have proven to effectively depress the population in these areas and facilitate other frogs to recover from local decline. Nevertheless, complete eradication is likely impossible by removal.

Current invasion patterns suggest the spread of this species will continue unabated. Management in the near future should focus on how the population size can be depressed and how to maintain the long term viability of native species. Current observations suggest this frog can utilize artificial water bodies and form large populations in disturbed areas. The removal of artificial water bodies could potentially reduce numbers of the frog without being harmful to native species. Ecological corridors between hot spots of this frog could be further interrupted by using fences in order to stop the expansion (Chang et al. 2013).

Trachemys scripta elegans (Wied, 1838)

Natural distribution. This freshwater emydid turtle (Fig. 4) is originally distributed in wetlands of southern United States, from Iowa to Florida, and northern Mexico, including Coahuila, Nuevo Leon and Tamaulipas (Ernst 1990, IUCN, Reptile database). It has invaded areas outside of its native distribution in USA and many countries worldwide, such as Australia (Burgin 2006), China (Shi 2000), France (Cadi

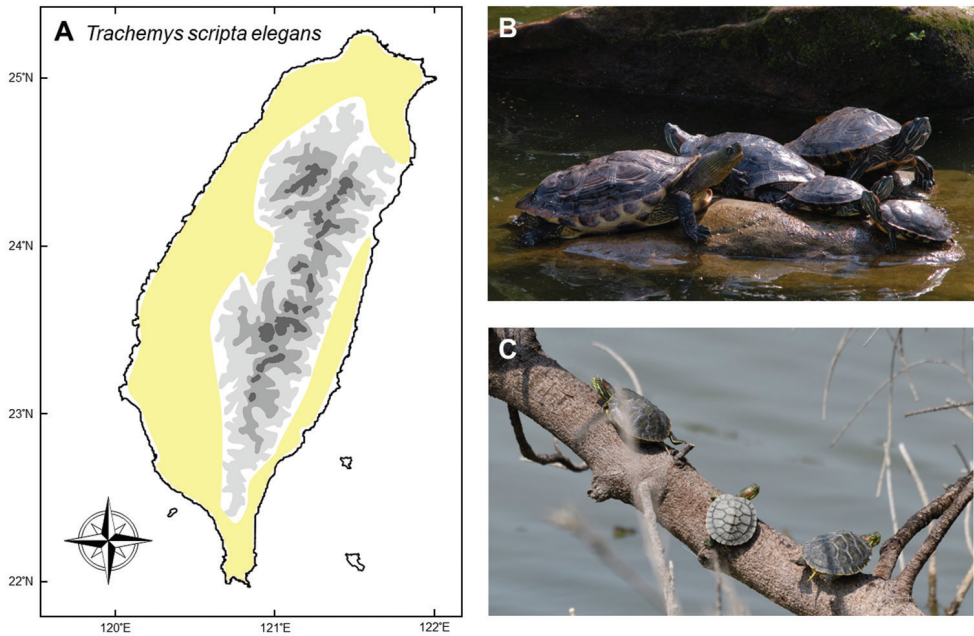


Figure 4. **A** *Trachemys scripta elegans* can be found in natural, semi-natural, or artificial wetlands in urban or suburban regions all around the island **B** they are usually found in sympatry with the native *Mauremys sinensis* **C** the hatchling turtles show their potential to reproduce in some habitats. Photographed by Gaus Shang (**B**) and Yu-Jen Liang (**C**).

et al. 2004), Italy (Luisellie et al. 1997), Japan (Uchida 1989, Ota 1995), and New Zealand (Thomas and Hartnell 2000). The IUCN lists this species as one of the top 100 of the world's worst invasive animals (Lowe et al. 2000). Turtle farms in the USA used to export millions of individuals every year to Korea, Japan, Thailand, and countries in South Africa and Europe, either for the pet trade or religious “Mercy Ceremony” (CITES Trade Database, Telecky 2001) and turtle farms bloomed in many Asian countries such as Thailand, Malaysia and China (Ramsay et al. 2007, Shi et al. 2008).

Colonization history. Invasion of this species can be traced to the late decades of 20th Century through intentionally being released by pet owners and religious activities (Ling 1972, Chen 2006). Chen and Lue (1998) reported the first record of feral populations in the Keelung River, Taipei; although the real age of their invasion must be much earlier. A more comprehensive survey in 2006 showed that this species had been distributed across western Taiwan, mostly in the northern and central regions, and also on Kinmen Islands (Chen 2006).

Nowadays, this species can be found in many aquatic systems in Taiwan, especially artificial ponds and rivers close to urban areas. Because of the pet market, citizens can get this species very easily, resulting in a fast assisted dispersal rate. Moreover, this species is sold near temples where Buddhists buy animals for their mercy ceremonies, which further facilitate this species to establish new populations.

Threats to native species and ecosystems. This species likely occupies most suitable water bodies through human-mediated dispersal (Heidy Kikillus et al. 2010). It co-exists with several other native chelonians (Chen 2006), such as *Mauremys sinensis* and *M. mutica* in Taiwan (Fig. 4B), and *M. reevesii* in Kinmen Island. Although evidence on direct competition is scarce, the threat to local ecosystems could be underestimated. First, it has been shown that *T. s. elegans* carried parasites which could switch hosts to *Mauremys leprosa* in northern Spain and southern France (Meyer et al. 2015). Second, this species is an opportunistic omnivore which can predate on aquatic animals and fishes (Chen 2006, Ma and Shi 2017), which means they can likely outcompete native turtles (Polo-Cavia et al. 2010). Third, exotic turtles may compete for microhabitats with native species. For example, *T. s. elegans* outcompetes native turtles for basking sites (Cadi and Joly 2003) and in experiments containing groups of native turtles and *T. s. elegans*, the native turtles experienced higher mortality (Cadi and Joly 2004).

Current status and trends. There have been no plans in Taiwan to remove this species from the wild, or to investigate its impacts. The importation and trade continues, with at least hundreds of thousands of young turtles being imported every year. In recent years, the government has invested heavily in development along the river, which has caused dramatic habitat loss on the riverbank. These constructions destroy nesting sites for native turtles located near the river banks. Since *T. s. elegans* tends to lay their eggs on muddy lands some distance from the riverside, there is likely higher survival rates of these nests leading to potential population replacement of the invasive species over native species (T-HC, pers. obs.).

Based on capture records (Chen 2006), the majority of this species now occurs in disturbed water bodies near urban areas, which indicates that their populations have not yet expanded to more natural environments. In most invaded regions, the population size has not yet exceeded *M. sinensis*, which is the most abundant native species (Chen 2006). The reason might be due to the low reproductive success and low survival rate for the hatchlings in the wild (but see Fig. 4C for the case of successful breeding in the wild), and secondly due to the fact that most pet keepers are not able to raise the imported young turtles to their adult size. Under this situation, removal of the adults might be effective in reducing their population size in the wild. A more permanent solution would be to cease the trade of this turtle. Eliminating this species from the wild would be difficult but possible, largely depending on serious coordination and will of the government.

Physignathus cocincinus (Cuvier, 1829)

Natural distribution. This large-sized agamid lizard (Fig. 5) is widely distributed across southern border regions of China and Indochina, such as Myanmar, Laos, Thailand, Cambodia, and Vietnam (Vassilieva et al. 2016). They have invaded Hong Kong (To 2005), Penang of Malaysia (Grismer 2011b), and Florida, USA (Ferriter et al. 2009), all believed to be through animal trades. It has not yet been assessed under the IUCN

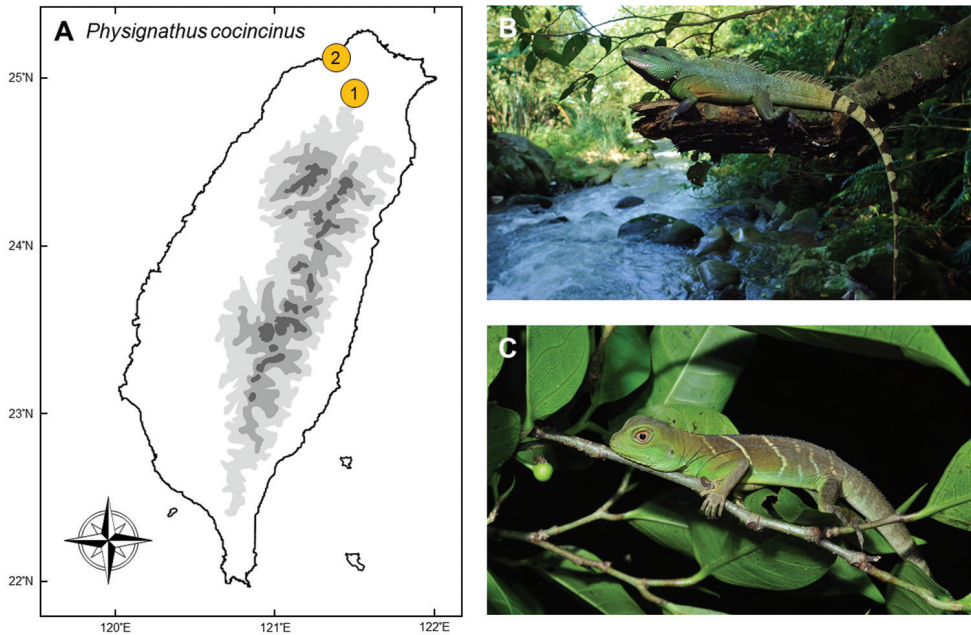


Figure 5. **A** The invasive population of *Physignathus cocincinus* was first established by an intentional release in Xindian (1), New Taipei City; and further transferred to Linkou (2), also believed to be intentional **B** the typical habitat of this semi-aquatic agamid is beside lowland streams **C** juveniles tend to rest on branches at night. Photographed by Ren-Jay Wang.

Red List, but the Chinese government has listed this species under China Species Red List (Wang and Xie 2009) due to high intensity hunting for animal trades.

Colonization history. The first Taiwanese population of *Physignathus cocincinus* was discovered in Ankeng, New Taipei City in 2010 by a deliveryman who saw an adult lizard basking on the road along a river (point 1 in Fig. 5A). Soon after, some reptile keepers and students confirmed that *P. cocincinus* had established a breeding population in this area. Five years later (in 2015), some “giant green lizards” were reported around Linkou District of New Taipei City (point 2 in Fig. 5A), 20 km away from Ankeng and spaced by dense urban areas, which were later identified as a second population of *P. cocincinus*. This species is confirmed to have been breeding in these two streams to the present.

Since the core zone of both these invasive populations are in wild, torrential streams which are far from human settlements, they are thought to be established by intentional release. In the late 20th century, *P. cocincinus* was valued as an alternative pet to the Green Iguana (*Iguana iguana*) when the latter was prohibited by the Conservation Act of Taiwan. In 2001, captive breeding individuals of *I. iguana* began to be legally imported, which made *P. cocincinus* became practically worthless. The origin of the Ankeng and Linkou populations are suspected to be due to releases by pet traders.

Threats to native species and ecosystems. *Physignathus cocincinus* is omnivorous, but primarily feeds on insects and snails (Manthey and Grossmann 1997, Ciou 2015). Research showed that adult *P. cocincinus* of the invasive population sometimes preys on native agamid lizards (*Diploderma swinhonis* or *D. polygonata*), frogs (*Buergeria robusta*), snakes (*Calamaria pavementata*), and mice (Ciou 2015) and thus could be a threat to many native animals along the stream systems, due to its large body size (SVL up to 250 mm and CL up to 650 mm (Vassilieva et al. 2016).

Current status and trends. The population in Ankeng did not initially show signs of quick spread because they were usually confined to riparian habitat along streams. During this period, some students, herpers, and pet keepers teamed up to remove this species from the wild. From 2013 to 2017, the government of New Taipei city further held projects to attempt to intensively remove this species. According to these surveys, more than 680 individuals were captured in Ankeng (Ciou 2015), with those removed by other citizens not included in this number. Removal of the Linkou population was conducted in 2016 and 2017, where approximately 200 individuals were removed. Research conducted at the time found that the population size could be effectively controlled with this intensity of removal, but would require consistent support from the government. Because of the species depends on streams, it might be possible to eradicate this species if the removal projects can be consistently sustained. We suggest that continuous support for these removal actions is a high priority with good chance of success, before the population spreads further and becomes impossible to remove. Actions to prevent further deliberate release or transportation of this species to other drainages should also be enacted.

Chamaeleo calyptratus (Duméril & Bibron, 1851)

Natural distribution. This large-sized Chamaeleon (Chamaeleonidae; Fig. 6) inhabits the tropical forests of south and southwestern Yamen, as well as southwestern Saudi Arabia (Tilbury 2010). This species has been introduced to Florida and Hawaii, USA (Krysko et al. 2004, Kraus and Fern 2004). In its native range, it faces a threat from collectors as it is a popular pet in wildlife trades. Although it is listed as “Least Concern” by the IUCN (LC; IUCN 2012), it is listed under CITES Appendix II as its trade should be closely controlled.

Colonization history. This species was first found on Cijin Island, ca. 200 meters offshore of Kaohsiung (point 1 in Fig. 6A), spotted along a beach by members of the public in 2011 and 2012 who uploaded photos of the animals on internet forums. At the time, these were considered as accidental escapes of pets, but another individual was captured during a fauna survey in Cijin in 2013 and further individuals have been found in the area since, including adults and adolescents (Fig. 6B, C).

Since the core zone of the chameleon population is located at the tip corner of an isolated peninsular, this invasive population was thought to be established by intentional release. As a popular and valuable animal in pet trades, captive breeding of this species is

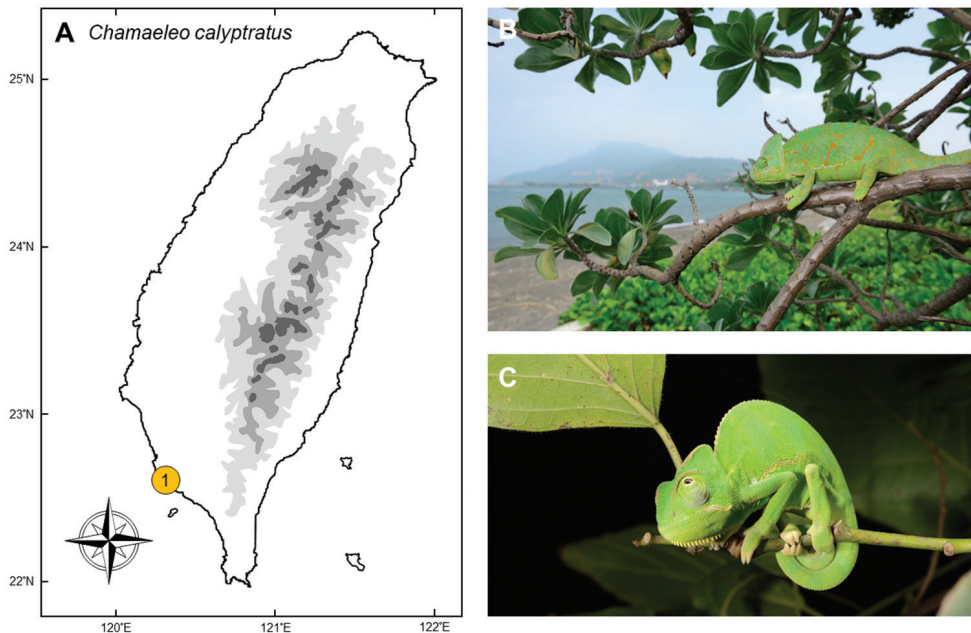


Figure 6. **A** The exotic population of *Chamaeleo calytratus* was established by intentional release in Cijin (1), Kaohsiung City **B** a female exhibiting its mature coloration in their invasive site **C** neonates provide evidence of successful breeding in the wild. Photographed by Chung-Wei You.

nevertheless difficult and costly. It was thus deduced that local pet traders released individuals deliberately so that they could “harvest” the young regularly and easily from the wild.

Threats to native species and ecosystems. *Chamaeleo calytratus* feeds mainly on insects, although large adults can prey upon small mammals and fledgling birds (Krysko et al. 2004). The invasive population of *C. calytratus* is now restricted to Cijin Island, where invasive species of cockroaches are the most abundant prey item. Although there is no evidence of further spread, they might compete with native tree lizards (*Diploderma* spp.) for food and habitat if the species is to establish and spread in the future.

Current status and trends. This species is currently restricted to a hill located on the northwestern corner of Cijin. Although eggs have never been found in the wild, hatchlings and juveniles have been found to constitute a large proportion of the population. Many gravid females have been captured with fertile eggs. Thus it is considered that this species has established a breeding population on the island.

No official project has been established to remove this population. However, news of their appearance attracted numerous students, reptile keepers, and pet traders to the island to attempt to catch this valuable pet in the summer of 2013 and 2014. This resulted in the population size decreasing. This species is now difficult to find there, which suggests that hand removal might be an effective management option.

Because this area is connected to Kaohsiung city only by ferry and an underwater tunnel, the spread of this species is likely to remain limited within the island. Nevertheless, invasion risk persists elsewhere with deliberate release from the pet trade.

***Iguana iguana* (Linnaeus, 1758)**

Natural distribution. This iguanid lizard (Fig. 7) is common in Central and South America, from south Mexico to Paraguay. It is a popular pet and has invaded many places, such as Florida (King and Krakauer 1966), Hawaii (McKeown 1996, Lever 2003), Fiji (Harlow and Thomas 2010, Thomas et al. 2011), Ishigaki Island of southern Ryukyus (Mito and Uesugi 2004; Falcón et al. 2013), and a large proportion of the West Indies (Falcón et al. 2012, López-Torres et al. 2012, Vuillaume et al. 2015). The invasive population in the West Indies has caused serious economic and ecological damage (Sementelli et al. 2008, Falcón et al. 2012). The species has not been assessed under the IUCN Red List but has been listed under CITES Appendix II, which limits the export of this species.

Colonization history. Although a popular pet in international reptile trade, keeping *Iguana iguana* was illegal in Taiwan until 2001 when the first captive bred individuals were legally imported. During 2002 to 2007, tens of thousands of green iguanas were imported into Taiwan each year (CITES trade database). In 2004, some juvenile *I. iguana* were found in the wild and sent to Pingtung Rescue Center, suggesting that some individuals had escaped from the pet trade.

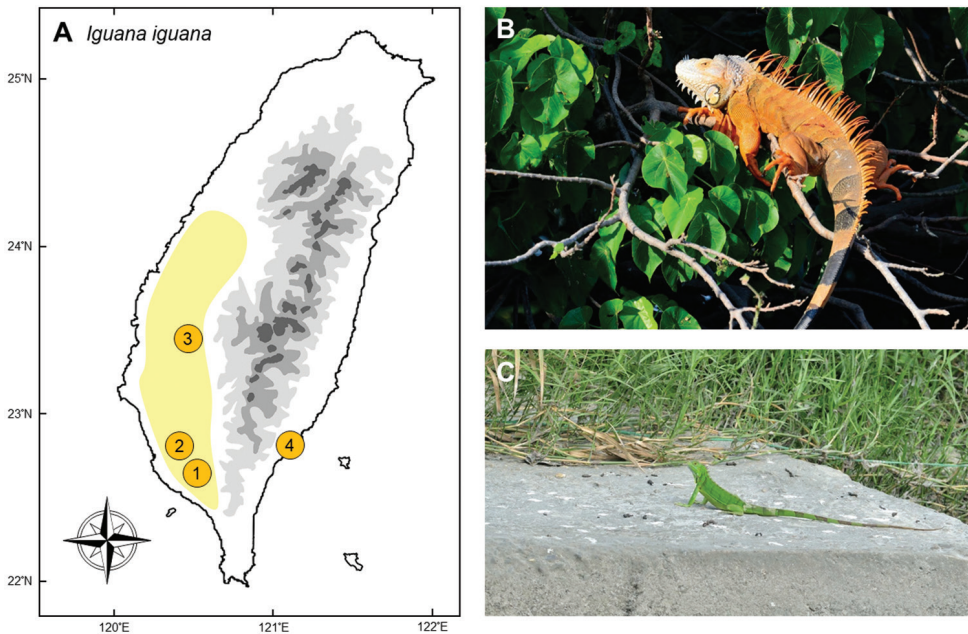


Figure 7. **A** The invasive populations of *Iguana iguana* were originally established by multiple intentional release events, specifically in Pingtung (1), Kaohsiung (2), Chiayi (3), and gradually expanded to become a continuous distribution. In 2018, a small disjunct population occurred in Taitung (4), which might be another human-induced translocation event **B** a mature male occupying the canopy during courtship exhibition **C** the large number of young lizards demonstrates breeding success. Photographed by Chung-Wei You.

Establishment of invasive populations in Taiwan originated from several independent incidents (Fig. 7A). The populations in Wandan of Pingtung County (point 1 in Fig. 7A) and Niaosong Wetland of Kaohsiung City (point 2) were the first two, which are thought to have originated from intentional releases by local breeders. Individuals from Niaosong were then captured, sold, and released to Bazhang River of Jiayi County (point 3), and Rende of Tainan City. Recently, newly established populations were found in Yunlin, Changhua, and Taichung Counties. A road killed individual and some living ones were caught in Taitung in 2018 (point 4), but whether it has established a population there remains unknown. Similar to the case of *Chamaeleo calyptratus*, local pet traders are suspected to have released this species intentionally for future harvesting.

Threats to native species and ecosystems. According to the experience of the Great Caribbean Basin, *I. iguana* can reach huge population sizes in suitable habitats (Falcón et al. 2012). Normally, they prefer forest edges near streams or rivers (Meshaka et al. 2004). Therefore, the tropical monsoon forests in southwestern Taiwan provides suitable habitat, and they are considered likely to expand to large numbers.

Based on analyses of stomach contents, invasive *I. iguana* populations in Taiwan feed mostly on *Broussonetia papyrifera* (Rosales, Moraceae), one of the most abundant shrubs in the disturbed areas of Taiwan. Although we do not have evidence on the threats to native ecosystems in the wild, human agriculture might be seriously damaged from adult iguanas which are able to wipe out the entire crops from the field within a few days. Digging burrows along river banks creates damage to the structure of irrigation channels, which can make structures unstable and threaten the safety of nearby citizens (Sementelli et al. 2008; Falcón et al. 2012). Female iguanas commonly use graveyards which causes damage to tombs, then interpreted as bad omens by the local people (interview records from local people).

Current status and trends. This species first established disjunct populations in southern Taiwan, and then gradually invaded into central Taiwan. During the invasion process, subordinate males play the role of dispersers into novel habitats at the invasion fronts, where they then occupy a territory and become dominant males (Fig. 7B). Females are then attracted by these males to the newly invaded sites (T-HC, pers. obs.). Compared to *P. cocincinus*, this species inhabits higher canopy in woodlands, which makes them difficult to be caught or to be removed. Accidental or deliberate releases by pet trader further make their spread out of control. Continuous captures of young individuals over time (Fig. 7C) suggests the feral populations of this species are consistently growing.

The Chiayi City Government has offered rewards for invasive *Anolis sagrei* for several years and *I. iguana* was included in this rewards program in 2017. However, this approach is considered ineffective by scientists as it has not resulted in population decreases of either of these two species. In southern Taiwan, Kaohsiung City Government conducted another project to evaluate the invasion of *I. iguana*. More than 2,200 adults were caught in Kaohsiung and Pingtung counties from 2013 to 2017 by T-HC's laboratory members, and this seems to have effectively reduced the population size (T-HC, unpublished data). We suggest that removal should focus on mature individuals near nesting sites before the breeding season, because dominant adults display strong

habitat loyalty during this period (T-HC, pers. obs.). A large proportion of the captured individuals from the government reward program, however, were young lizards which naturally have very low survival rate in winter (T-HC, pers. obs.), which made this program inefficient. We conclude that complete eradication is unlikely in Taiwan; but more efficient management policy could help to depress their population.

Anolis sagrei Duméril & Bibron, 1837

Natural distribution. This small-sized anole (Dactyloidae; Fig. 8) is widespread across the islands of Bahamas, Cuba (Campbell 1996), Honduras (Rodríguez Schettino 1999), and several islands nearby, such as Swan Island (Rodríguez Schettino 1999), Cayman Brac and Little Cayman (Losos et al. 1993). Although it seems that this species is widely distributed in Central America and the Caribbeans, many of the populations, including those in Jamaica, Grand Cayman (Roughgarden 1995), Belize (Rodríguez Schettino 1999), Grenada (Greene et al. 2002), and the East Coast of Mexico (Conant and Collins 1998) are invasive. It is also introduced to several regions of the USA, for example, Florida, Texas (Conant and Collins 1998), Louisiana (Steven and Lance 1994), Georgia (Campbell 1996), and even Hawaii (Kishinami and Kishinami 1996). Recently, it has been reported to have invaded Singapore, possibly with imported plants (Tan and Lim 2012). This species is not listed under any endangered species legislation and frequently appears on alien species lists in many countries.

Colonization history. The first record of this species was in September of 2000, when one female and two males were found beside a road near a plant nursery in San-jiepu, Chiayi by Gerrut Norval (point 1 in Fig. 8A). These individuals were captured and sent to the Senckenberg Museum for confirmation of identification. In November 2000, 28 individuals were collected in the same area, and preserved in the National Museum of Natural Science (Norval et al. 2002).

It remained unknown how this species entered Taiwan, but we deduce that potting compost imported to the nursery likely contained eggs of this species, as was observed during its invasion onto Guana Island (Perry et al. 2006). The most likely source of this population is thought to originate from Florida, because of the similarity in parasite composition and mitochondrial sequences (Kolbe et al. 2004, Norval et al. 2011). In 2006, this species was first recorded in Hualien City (Chang 2007), with a huge population in Chicingtan and several satellite populations such as Hualien City and the campus of Dong Hua University. Around 2014 – 2015, a third population was discovered in Hsinchu. This species is now confirmed to occur in three localities: Chiayi, Hualien, and Hsinchu (Fig. 8A).

A. sagrei expands quickly once introduced to new areas and may adapt to new environments well due to its high genetic variation (Losos et al. 1993, Gerber and Echternacht 2000, Kolbe et al. 2004). An investigation in 2007 showed that *A. sagrei* occurred in more than a quarter of the sampling sites in Santzepu, Chiayi (Hou et al.

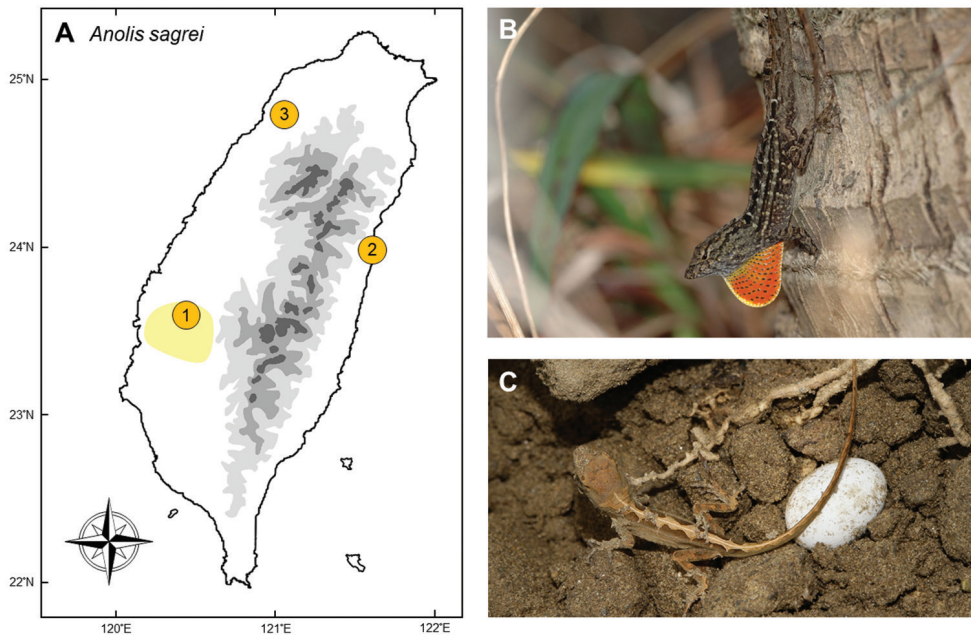


Figure 8. **A** The population of *Anolis sagrei* was first discovered in Jiayi (1), southwestern Taiwan. Subsequently, this lizard occurred long-distance dispersal to eastern (Hualien (2)) and northwestern (Hsinchu (3)) Taiwan **B** a mature male showing courtship exhibition on a trunk in the invasive region **C** an egg and a hatchling of *A. sagrei*. Photographed by Ren-Jay Wang (**B**) and Wen-Bin Gong (**C**).

2007). After six years, the distribution of this species became even wider, and one third of the sampling sites in Santzepu was reported to be inhabited by this species (Wang 2013).

Threats to native species and ecosystems. *Anolis sagrei* occupies the tree-trunk niche within its habitat (Fig. 8B). In invaded zones, this species reaches tremendous numbers with extremely high population density, and is probably capable of out-competing other arboreal insectivorous vertebrates. In Hualien, populations of the grass lizard *Takydromus luyeanus* (Lacertidae) have declined dramatically in sympatric sites (Yang 2017), while their impact on the tree lizard *Diploderma swinhonis* (Agamidae) remains unknown and needs further monitoring. Predation by the species has also altered communities of invertebrates, particularly ants (Huang et al. 2008).

Current status and trends. In order to persuade citizens to help remove the lizards, the Chiayi County Government has offered rewards for carcasses of the anoles since 2009. However, this policy was regarded as being inefficient. The rewards have encouraged locals to accumulate huge amounts of carcasses, but this has not been effective in removing the population. We suggest several reasons for this: first, most citizens try to catch the lizards from the core zone(s) of the invasion, where high densities of lizards facilitate people to earn the reward with the least effort. However, individuals can quickly fill these gaps from adjacent regions and the population is thus impossible to eliminate. Second, with a long breeding season and continuous clutch production, it is ineffective when only a low proportion of individuals are

removed. Although huge amounts of money have been spent on removing individuals every year, the distribution of this species is still expanding rapidly in western Taiwan. In contrast, the research team in Hualien, eastern Taiwan used an alternative strategy. Instead of citizens, volunteers were trained to focus on invasion fronts. By removing individuals from the front, the team led by Dr. Yi-Ju Yang has successfully reduced the speed of the invasion, and successfully eliminated some newly established populations. To date, the Chiayi population is continually expanding, but the expansion in Hualien has been slowed.

Current evaluations indicate that the expansion of *Anolis sagrei* is unstoppable and that regions which have already been invaded, eradication is likely impossible. The only thing we can do is to slow down the expanding speed of the front. Transportations of potted plants from core regions of lizards should be quarantined (Campbell 1996, Norval et al. 2017). Maintenance or restoration of the natural habitats can also help with stopping the spread of this species in rural areas.

***Gekko gecko* (Linnaeus, 1758)**

Natural distribution. This large-sized gecko (Gekkonidae; Fig. 9) is widely distributed in southern Asia, including southern China, Indochina, Malaysia, Indonesia, and the Philippines (Rösler et al. 2011). It has been reported to have invaded the Caribbean (Henderson et al. 1993), Hawaii, Florida (Kraus 2009), Belize (Caillabet 2013), Madagascar (Das 2015), and Brazil (Júnior 2015). This species has not yet been assessed under the IUCN Red List, and it is not listed under CITES.

Colonization history. Early records of this species in Taiwan can be traced back to the Japanese colonial period (Okada 1936). Two records of this species have been documented, both with only a single individual; one occurred in the botanic garden in Taipei, the other was caught by a junior high school student in Tainan. Because of its rareness, this species was listed in the first version of the Conservation Act in the 1980s. However, herpetologists now regard these records as accidentally imported individuals and removed this species from the protected list.

Rediscovery of this species occurred in 2008, when five individuals were found in Taichung (point 1 in Fig. 9A) (Norval et al. 2011). In 2013, an egg litter and a hatchling of this species were discovered by Ming-Hung Hsu and Chi-Yu Huang in a fauna survey in Kaohsiung, representing the first breeding population ever found in Taiwan (point 2). In addition to Kaohsiung, it has also been sporadically reported in several other places such as Neipu township of Pingtung (point 3). This species might have been carried to these areas accidentally either by cargo ship or escaped from pet owners.

Threats to native species and ecosystems. We have recorded individuals regurgitating invasive species of cockroaches after being captured. Therefore, we suspect that they prey mainly upon cockroaches around houses, with some other small invertebrates and vertebrates. Besides direct predation, *G. gecko* may compete with other native geckos.

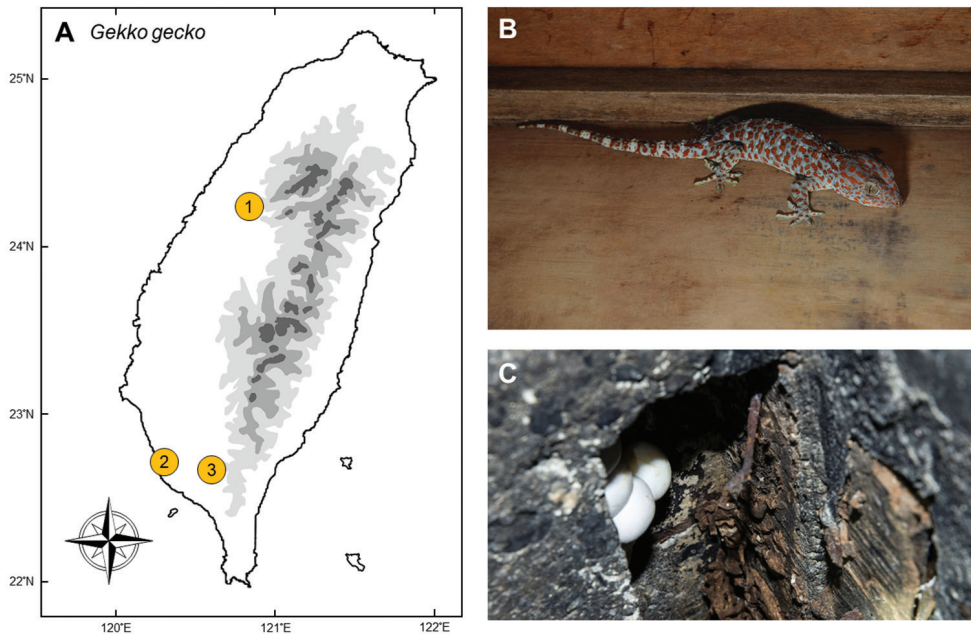


Figure 9. **A** *Gekko gecko* has been discovered in several disjunct localities (Taichung (1), Kaohsiung (2), Pingtung (3)), which was thought to be from multiple release events **B** a mature gecko showing defensive posture on a cornice in Kaohsiung **C** eggs in a nearby cave. Photographed by Ren-Jay Wang (**B**) and Ko-Huan Lee (**C**).

Current status and trends. Although distributed sporadically in a few places, only the population in Kaohsiung has been confirmed as a reproducing population. Distribution of this population is restricted to Guishan hill near Lienchi Lake, Zuoying District. Individuals occur around buildings and nearby forests, which is similar habitat to that which this species uses in native areas. There is currently no specific program to eradicate the species. However, the population size has been depressed through spontaneous capturing programs organized by students and pet keepers. Fortunately, Guishan is isolated from nearby natural habitats by urban areas which might prevent *G. gecko* from spreading to other natural habitats. However, a comprehensive survey is still required to investigate the dynamics of this population, especially with the risk that pet keepers might release more individuals to other localities.

Gekko monarchus (Schlegel, 1836)

Natural distribution. This medium-sized gecko (Gekkonidae; Fig. 10) occurs throughout the Philippines, Singapore, Peninsular Malaysia, reaching to southern Thailand (from Narathiwat to Surat Thani), Indonesia, including several islands (e.g., Aru Islands, Kei Islands, Ambon Island), and can be as far east as New Guinea (Pauwels

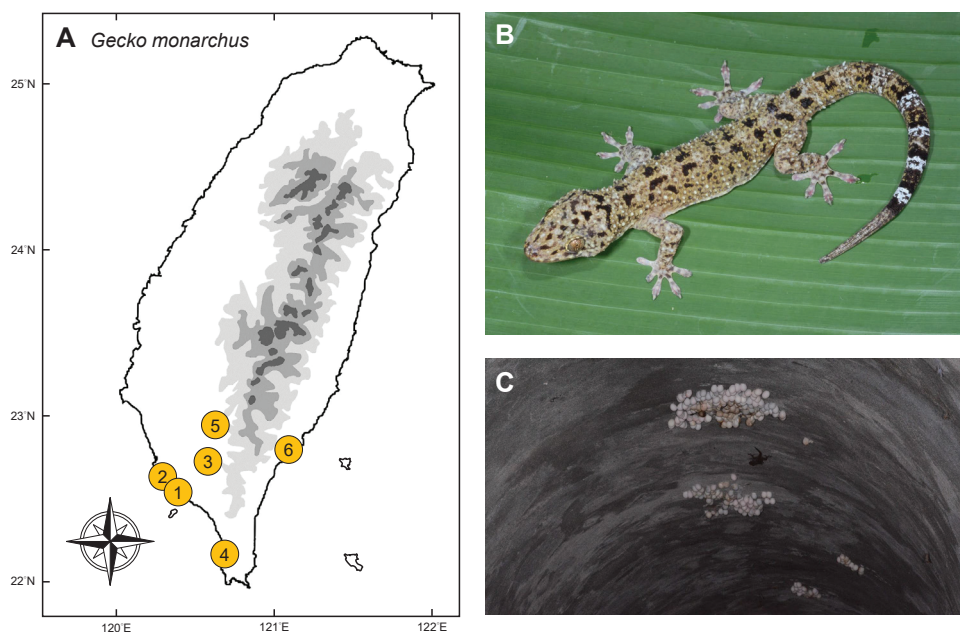


Figure 10. **A** Invasion of *Gekko monarchus* is thought to have occurred from international timber trades near the Kaohsiung Harbor ((1) and (2)) and a log-processing area (3). In 2018, the newest population was found with disjunct distribution in Taitung County (4) **B** a mature individual **C** a large colony of eggs. Photographed by Gaus Shang.

and Sumontha 2007, Rösler et al. 2011). It has been reported to have been accidentally imported to New Zealand and South Africa (Gill et al. 2001, Bauer and Branch 2004). This species has a wide distribution, and is locally abundant throughout most areas. It is not listed as threatened under any legislative acts.

Colonization history. This species was first discovered in 2009 from Linyuan District, Kaohsiung by locals (point 1 in Fig. 10A) and later identified and confirmed by Dr. Szu-Lung Chen (Shang 2013). In 2010, researchers of Observer Ecological Consultant Company recorded a second population in Fengbito, Kaohsiung (point 2). The third population in Neipu, Pingtung County (point 3) was reported by Ching-Gou Ji in the same year. In 2016, Shang et al. (2016) estimated that there were approximately 200 individuals in Linyuan, 1,000 in Fengbito, and 100 in Neipu. In 2017, this gecko further colonized Checheng (point 4) and Liugui (point 5). Since 2018, a newly established population was found in Taitung City (point 6), with a disjunct distribution far away from the western populations. In addition to these populations, sporadically caught individuals were also reported from Renwu in 2012, Chiayi in 2012, Yilan in 2012, and Nantou (2013).

How this species entered into Taiwan remains unknown, but it is thought to be related to the timber trade of Kaohsiung Harbor (point 1 and 2 in Fig. 10A), as two of the three originally invaded localities are near industrial zones. The species lives close

to humans in its native range (Grismer 2011a, b), and is thus likely to gain access to importation cargos from southeast Asia. New localities have been reported far from the originally colonized areas every year, which implies that this species is likely invading these areas through human mediated dispersals.

Threat to native species and ecosystems. *Gekko monarchus* eats small invertebrates in its native range. In Taiwan, it preys primarily upon Coleoptera and Blattodea (Shang et al. 2016), with small snails, egg shells and seeds also occasionally recorded from stomach contents. In invaded regions, this gecko out-competes other geckos such as *Lepidodactylus lugubris* on Pulau Cebeh (Grismer 2011a). This species can occur in high densities in a variety of habitats, and can be the most dominant lizard on some islets (e.g., Cebeh of Seribuat Archipelago) (Grismer 2011a). As a result, this species is capable of dominating many lowland habitats and possibly wipe out native geckos.

The most crucial task in the near future would be preventing this species from moving onto Orchid Island, an offshore islet with only 48 km², which is occupied by *Gekko kikuchii* (Oshima, 1912), a species closely related to *G. monarchus* and confined to this island within Taiwan (Siler et al. 2014). *Gekko kikuchii* is similar with *G. monarchus* in body size, predicting large niche overlap with each other, once they occur sympatrically. Thus, if invasion of *G. monarchus* occurred on Orchid Island, it is thought probable to wipe out the population of *G. kikuchii*.

Current status and trends. In Taiwan, this species lives close to humans and disturbed areas such as buildings or tunnels (Shang et al. 2016). Shang et al. (2016) estimated the population size of Fengbito to be 5,029 individuals using mark-recapture methods. A large proportion of individuals inhabit military tunnels beneath subtropical forest, which makes them difficult to be eradicated.

An eradication program was conducted by the Forest Bureau from June to December, 2015. A total of 532 individuals were caught, with more than 4,000 eggs being destroyed from three main invaded regions, mostly from Linyuan (Shang et al. 2016). Shang et al. (2016) suggested that removal plans should continue to restrict the population size, and to stop the invasion progress. However, the government seems unwilling to continue the program to eradicate this species. Based on current situation, it has a high potential to spread widely through southern Taiwan within a short period.

Hemidactylus brookii Gray, 1845

Natural distribution. This small-sized gecko (Gekkonidae; Fig. 11) is widely distributed in Central America, tropical Africa, Asia, including the Indian subcontinent, Indochina and Indonesia (Kluge 1969, Bauer et al. 2002). Owing to the extremely wide-range distribution, the taxonomy, phylogeography, and invasion status of *Hemidactylus brookii* sensu lato was controversial and attracted the interests of researchers (Bauer et al. 2010, Mahony 2011, Lajmi et al. 2016). Currently, the nearest population is in Hong Kong, which was described as an invasive species (Romer 1977). It is not listed as threatened under any legislative acts.

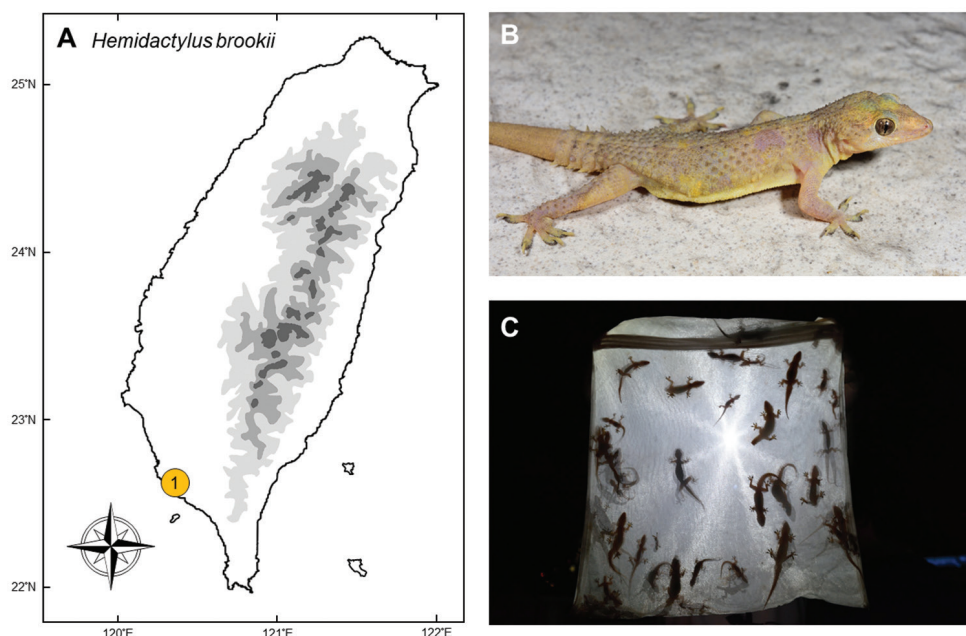


Figure 11. **A** *Hemidactylus brookii* is the most-recent invasive species which was discovered from a single population along the river banks of Love River, Kaohsiung City, southern Taiwan (**1**) **B** a mature male **C** large amount of young geckos indicated that they have successfully colonized in the city. Photographed by Chung-Wei You.

Colonization history. This recently discovered species was found along the river banks of the Love River in Kaohsiung City (point 1 in Fig. 11A). June 2018, a college student Dong-Long Yeh took some photos from an unidentified gecko. He sent these photos to Chung-Wei You, a herpetologist who has plenty of experiences to observe herpetofauna worldwide. Although it was an individual with a regenerated tail, it was identified as a Brooke's house gecko (*Hemidactylus brookii*) by You. He organized a team in July 2018 to investigate whether it had established a population along the river side. During this survey, they identified and spotted numerous Brooke's house geckos along the river, and captured 36 individuals including eight males, eleven females, and 17 juveniles. Large numbers of juveniles indicated that this gecko has successfully colonized in the city (You 2019). It remains unknown how and when this species invaded Kaohsiung. It was suspected that this species was introduced by cargo ships from nearby harbors.

Threat to native species and ecosystems. Feces of *H. brookii* were collected to identify its diet in Kaohsiung. Diverse insects were identified using microscope, including Coleoptera, Orthoptera, Hemiptera, Diptera, Dermaptera, and Araneae, on which endemic geckos also prey (You 2019). The influence of *H. brookii* on local ecosystems and whether it competes with native or other invasive geckos remains unstudied.

Current status and trends. This species mainly dwells in the cement river bank along the Love River, and occasionally spotted in the bushes. A large population was found sympatric with native *Gekko hokouensis* and suspected invasive *Hemidactylus frenatus*. The large number of juveniles seen in this population suggests that this species

has been breeding in this area, despite no eggs and gravid females were found during the survey. Based on this observation, You (2019) further deduced that *H. brookii* has a high potential to spread along the river bank to nearby urban or suburban regions. Since this is a newly discovered species, there is no eradication program to control the population size.

***Eutropis multifasciata* (Kunl, 1820)**

Natural distribution. This medium-sized skink (Scincidae; Fig. 12) has a wide distribution in eastern Asia, from India to southern China, including Thailand, Myanmar, Laos, Cambodia, Vietnam, and Malay Peninsula. It is also common on some islands of the Philippines, Indonesia, and New Guinea (Vassilieva et al. 2016). It has also invaded Florida, USA (Meshaka 1999). It is not listed as threatened under any legislative act.

Colonization history. This species was first recorded in Meinong District and Chengcing Lake, Kaohsiung in 1992 (Ota et al. 1994) (point 1 in Fig. 12A) by Prof. Hsueh-Wen Chang and his lab members and thought to have had already established a breeding population prior to this time. It was thought likely to be introduced into Taiwan by cargo ship, presumably through the international timber trade. Two years after its first discovery, populations were found in Fongshan, Ciaotou, and Chaujou (Chang and Liu 1995). During the period of 1999 to 2002, fauna surveys conducted by Endemic Species Research Institute showed that this species had expanded its population southward to Fangliau, northward to Rende (Lin 2008, Tseng and Lin 2008), and also successfully colonized Siao Liouciou (point 2 in Fig. 12A), a tiny islet located 15 km from the western coastline of Taiwan (Shang 2001). By 2007, the invasion front had extended from Cigu to Dounan, although it seemed to stop on the southern side of the Jhuoshuei River (Tseng and Lin 2008), a new, isolated population of *E. multifasciata* was found in a submontane area of Puli (the northern side of Jhoushuei River) in 2014.

Although all of these localities are in western Taiwan, Green Island (point 2) and Orchid Island (point 3), located 33 and 72 km off shore from the east coast of Taiwan, have been reported to contain populations of *E. multifasciata*. The first record of this species on Green Island was a carcass, presumably killed by cats, in 2008. In the same year, Researcher Te-En Lin, confirmed that a population consisted of approximately one thousand individuals had successfully colonized around the Green Island lighthouse. On the other hand, *E. multifasciata* has been recorded for several years on Orchid Island with the population size not well documented and time of invasion unknown.

Whether this species immigrated to Green Island and Orchid Island through natural dispersal or artificial introduction remains controversial. For instance, previous research on reptiles (Ota and Huang 2000, Siler et al. 2014), birds (Oliveros and Moyle 2010) and beetles (Tseng et al. 2018) indicated a northward stepping-stone dispersal model across the Taiwan-Luzon volcanic belt. Furthermore, Kurita and Hikida (2014) revealed that the Ryukyu Five-Lined Skink could disperse northward via the Kuroshio Current. Further research is needed to verify the source and mode of introduction of *E. multifasciata* to Green and Orchid Islands.

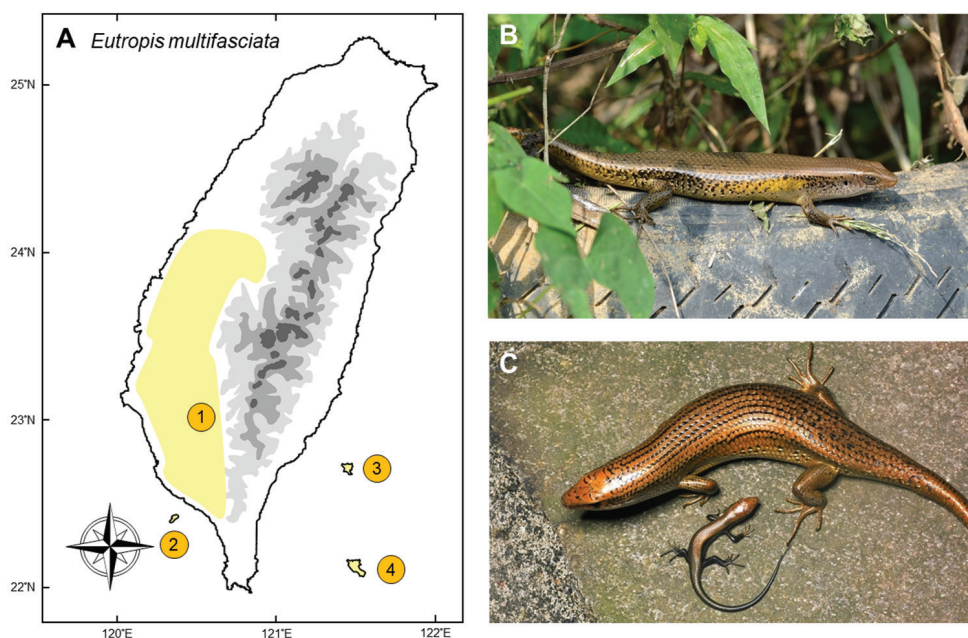


Figure 12. **A** *Eutropis multifasciata* has originated from Meinong (1), expanded to the entire southwestern Taiwan, and also colonized offshore islets such as Siao Liouciou (2), Green Island (3), and Orchid Island (4) **B** an adult male basking on an abandoned tire along a river bank **C** a mature female with her new-born baby. Photographed by Chung-Wei You (**B**) and Ren-Jay Wang (**C**).

Threat to native species and ecosystems. *Eutropis multifasciata* is a viviparous skink which breeds all year round with 4–12 neonates per litter (Chang and Liu 1995, Shang et al. 2009). Such productivity gives this species an advantage to adapt to disturbed regions and further expand its population. *E. multifasciata* occupies a variety of habitat types in southwestern Taiwan, including coastal areas, open forests, rural grasslands, disturbed lowland areas, and submontane areas, but prefers living in ditches and water channels. The ability to dive into water when encountered by predators also serves to provide them a better chance to explore novel habitats. By being semiaquatic, this species can spread quickly by using irrigation throughout agricultural lands.

Scientists suspect that the congener *Eutropis longicaudata* would be the first native species to be impacted from the invasion, because *E. multifasciata* has a much higher fecundity than *E. longicaudata*. *E. longicaudata* laid an average of ten eggs three times annually, while *E. multifasciata* can give birth to 4–12 hatchlings up to five times every year (Chu 2000). To date, it appears that habitats previously occupied by *E. longicaudata* have gradually been replaced by *E. multifasciata* (K-HL, pers. obs.). Their invasion is also likely having serious impacts on several endemic skinks, such as *Plestiodon leucostictus*, which was recently elevated to species status from subspecies (Kurita et al. 2017) and has a unique color morph on Green Island (Hikida 1988), suggesting a distinct evolutionary unit for this population.

Current status and trends. In the early 20th century, *E. multifasciata* had been one of the major targets of government-funded monitoring. It now appears to be impossible to eradicate, with *E. multifasciata* having become one of the most abundant skinks south of the Jhuoshuei River, with the highest population density being in southern Taiwan (Tseng and Lin 2008). Endemic Species Research Institute has attempted an eradication program on Green Island where its habitat significantly overlaps with *P. leucostictus*, but the population still persists. The northward expansion of this species is still ongoing and thought to be largely unstoppable.

Species with a controversial status

Lithobates catesbeianus (Shaw, 1802)

Notes. Captive breeding of this large ranid frog (Fig. 13) for food started in the 1950s in Taiwan. Nowadays, tens of thousands of bullfrogs are sold from commercial farms every year. Occurrence of the bullfrog in the wild is a common consequence of intentional release for religious mercy ceremonies. Although likely to have occurred much earlier, this situation was not noticed until the late 1980s. Since first included in the amphibian guide by Lue and Lai (1990), most guide books and fauna reports have included the bullfrog as an invasive species in Taiwan (Shang et al. 2009, IUCN SSC Amphibian Specialist Group 2015).

Mature individuals, froglets, and tadpoles are all potential targets for release ceremonies. Therefore, a variety of frog sizes have been discovered in the wild. Nevertheless, despite common records around the low land habitats of Taiwan (Fig. 13A), successful breeding by the frog in nature is rare, possibly due to the higher temperatures in Taiwan compared to its native range (see a comparison between native and invasive regions; Degenhardt et al. 1996). Some released adults (Fig. 13B) survive for a while and produce breeding calls, but most of them do not breed. Most froglets die soon after release, and there is no evidence to show that these frogs can reach sexual maturity in the wild, although the reasons why are poorly understood. In 2009, Gaus Shang recorded a group of tadpoles near Xindian Stream, New Taipei City (Fig. 13C), representing one of the very few cases of suspected breeding by this frog in the wild, but the population did not persist. This suggests that the bull frog is capable of breeding in Taiwan, although a breeding population has not yet been recorded to have successfully established. Because of the limited evidence for their reproduction in the wild, the status of this species should perhaps be revised to reflect that they are continuously released into the wild, rather than constituting an actual “invasive” population. While the failure of breeding in the wild is suspected to be a consequence of the relatively higher temperatures in Taiwan (Degenhardt et al. 1996), the mid-elevation areas in Taiwan have the potential to provide lower temperatures to support their breeding. Large water bodies at these regions should be monitored to prevent this species from establishing “real” breeding populations.

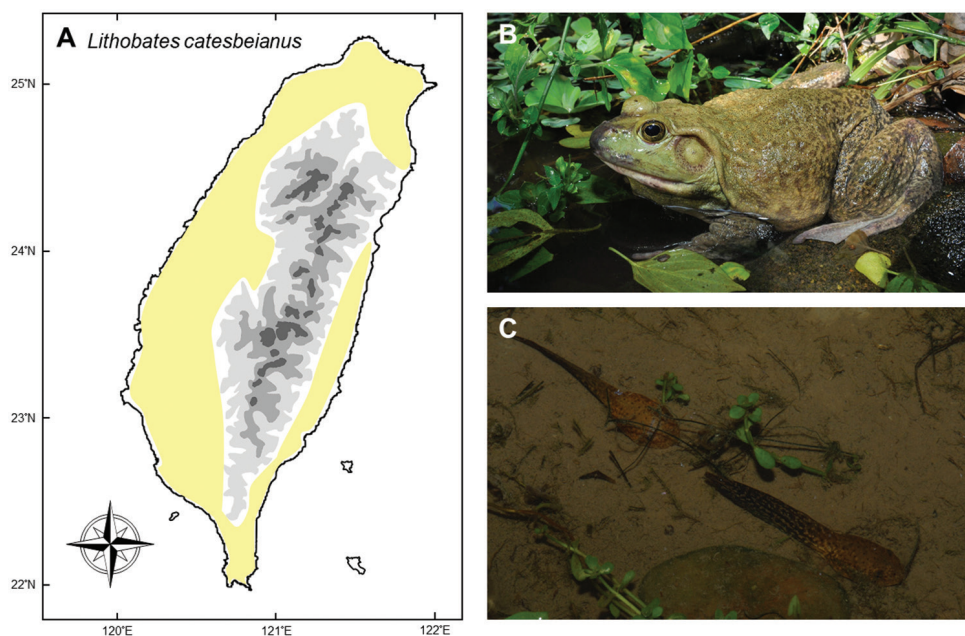


Figure 13. **A** Escaped or released *Lithobates catesbeianus* has been recorded almost all around Taiwan **B** the injured snout of this adult indicated it is recently released from captivity. However, it seems that they have not established a successful breeding population **C** one of the very rare cases of tadpoles found in the wild was discovered by Gaus Shang. Photographs by Ren-Jay Wang (**B**) and Gaus Shang (**C**).

Mauremys reevesii (Gray, 1831)

Notes. This moderate-sized fresh water geoemydid turtle (Fig. 14) is distributed throughout central and eastern China and the Korean peninsula. Although the wild populations have experienced dramatic population decline due to commercial over-exploitation in China, the captive populations might have become one of the most common species in Chinese turtle farms. It has been introduced into Indonesia, Palau, Timor-Leste, Japan, and Ryukyu Archipelago (Lovich et al. 2011). The introduced population in Japan (Hikida and Suzuki 2010) has caused hybridization with the endemic *M. japonica* (Suzuki et al. 2013), and was thus regarded as a threat to the genetic integrity of the latter (Suzuki et al. 2011, Suzuki et al. 2013).

The first record of this turtle in Taiwan was reported by Horikawa (1934), who discovered this species in 1931 near Taipei Basin. Thereafter, most of the records occurred in Tamsui River drainage (Mao 1971) of Taipei, one of the most seriously polluted and disturbed rivers in Taiwan (Fig. 14A). The population size had never been evaluated until the late 1980s, when the first version of the Conservation Act of Taiwan listed it as a threatened species (Class III). The population in the Tamsui River

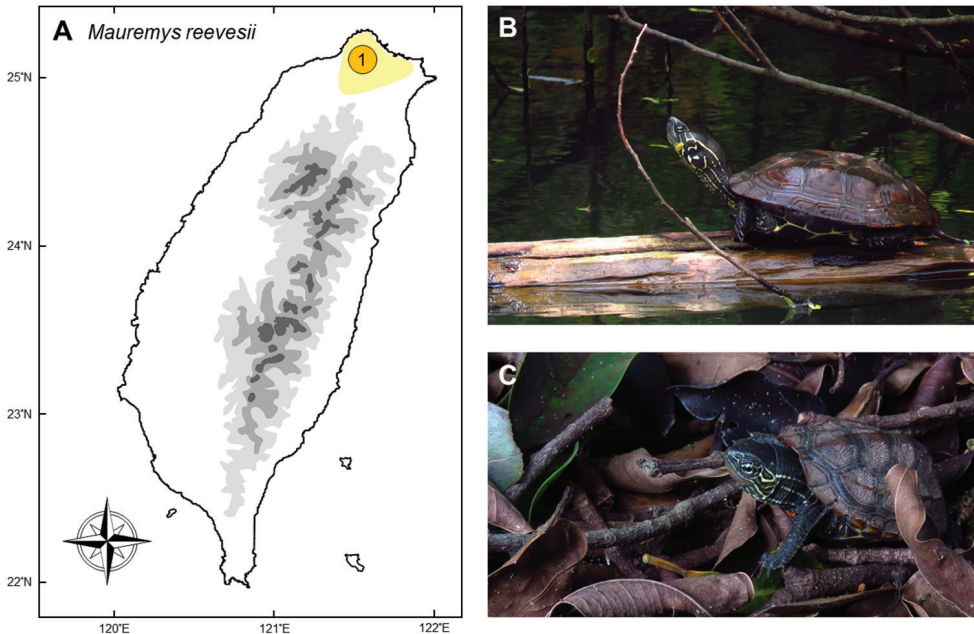


Figure 14. **A** Most confirmed records of *Mauremys reevesii* in the 20th century are from the Tamsui River Drainage (1) close to the highly developed Taipei City, where this population has gradually gone extinct in the late 1980s **B, C** the pictures of the adult and the young were taken from a native population on Kinmen, an islet 3 km offshore from China. Photographed by Wei-Lun Lin.

seemed to have declined dramatically in the 1980s and 1990s. In the late 1990s and early 2000s, several thorough investigations (Chen and Lue 2010) indicated that this species might have gone near-extinction in Taiwan. In 2008, a revised list of protected species under the Conservation Act reevaluated this turtle as a “critically endangered species” (Class I), which was the highest rank among all reptiles in Taiwan.

Although currently listed as a threatened native species, this status has recently been challenged by Fong and Chen (2010) for a number of reasons. First, the discovery of this species in the 1930s was 70 years after the first systematic investigation of Taiwanese fauna when Robert Swinhoe visited the island in the 1860s. It is worth to note that the majority of herpetofauna has been uncovered before the early 1930s; until a new wave of new species and new records in the late 20th century. The age of discovery of *M. reevesii* was not only much later than any other testudine, but also one of the latest among all herpetofauna in Taiwan before World War II. Second, confirmed individuals were restricted to the Tamsui Drainage (Mao 1971), a highly disturbed area close to the most developed city in Taiwan, Taipei City. Third, it is hard to explain why this species has never been found elsewhere in other natural drainages which retain much better environments. Together, these facts led Fong and Chen (2010) to suspect that this turtle is actually introduced by Chinese immigrants in the early 20th century.

In order to trace the origin of *M. reevesii* of which the status was also controversial in Japan, Suzuki et al. (2011) used molecular approach to study the population genetics of this species; the samples comprised a native individual from Taiwan. Their results indicated that the genetic divergence among China, Japan and Taiwan populations was far below than the expectation deduced from other terrestrial taxa. Suzuki et al. (2011) thus made a conclusion which was congruent to Fong and Chen (2010), that both Japanese and Taiwanese populations of *M. reevesii* were originated from human release. This deduction was also referred in the review by Lovich et al. (2011).

The reason for the disappearance of this turtle in the Taipei Basin remains a mystery. Habitat destruction could be a major reason, while hybridization and backcross to the dominant native congener *M. sinensis* could be another, as mitochondrial sequencing has shown hybridization between the species and intermediate forms exist (Fong and Chen 2010, Chen and Lue 2010). Nowadays, *M. reevesii* individuals are occasionally found in other drainages of Taiwan, but have never proven to constitute a breeding population. These new individuals presumably originated from Chinese turtle farms and are likely to be released from pet keepers.

Hemidactylus frenatus Dumeril & Bibron, 1836

Notes. This small-sized, house-dwelling gecko (Fig. 15) is one of the most notorious, successful, and weedy invasive reptile in the global scale (Carranza and Arnold 2006, Behm et al. 2019). In Taiwan, it is not only the most common gecko, but perhaps the most abundant reptile on the island. Since first reported by Boulenger in 1885, it was always treated as a native species throughout the 20th century. However, several lines of evidence, such as geographic genetic pattern (Moritz et al. 1993), or the range expansion in nearby regions (Hunsaker 1966, Case et al. 1994), suggest that most *H. frenatus* populations in the world are exotic. Another line of evidence came from the phylogeny of *Hemidactylus* spp. (Bauer et al. 2010), which indicated that *H. frenatus* belongs to a species-rich clade with all its members distributed exclusively in southern Asia. Ota et al. (2004) formally recognized the populations in Ryukyu Archipelago as invasive, and further interpreted that the current populations on most Oceanian and East Asian islands were similarly derived from human-associated dispersals. This was also emphasized in Kraus (2009), and this species is now considered invasive in many countries. Currently, the IUCN lists the occurrence of *H. frenatus* in Taiwan as an introduced population; the Global Invasive Species Database (GIBD) website categorizes it as “cryptogenic”, and treats adjacent regions (Japan and the Philippines) as introduced.

Historical observation indicated that *H. frenatus* and *H. bowringii* occupied the southern and northern parts of Taiwan, respectively (Ota 1989, Lin and Cheng 1990). However, *H. frenatus* has now expanded all around the island, including the northern third of the island which was not occupied by this species several decades ago (Ota

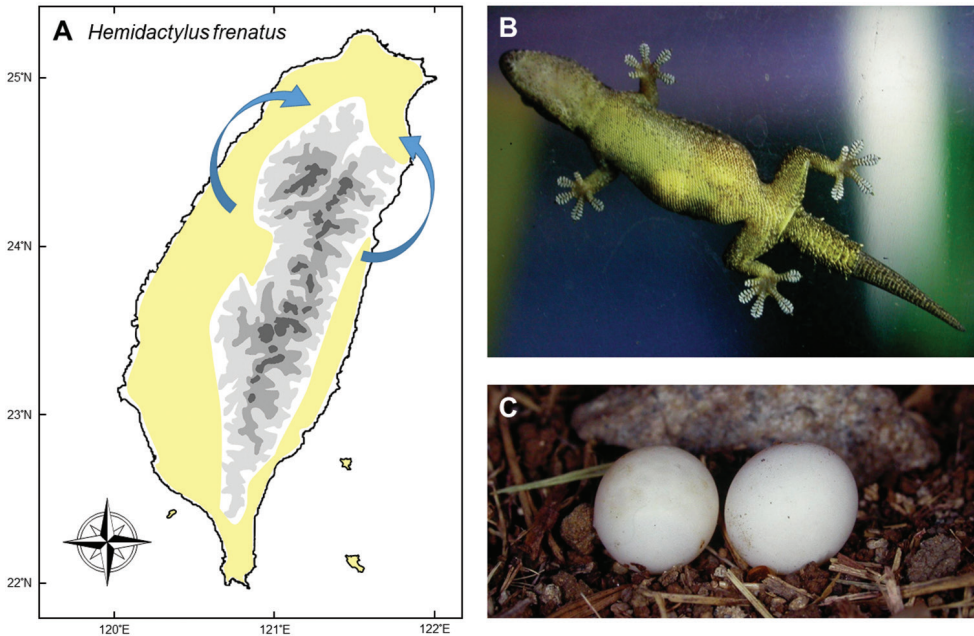


Figure 15. **A** *Hemidactylus frenatus* has expanded not only throughout the lowland of Taiwan, but also almost all islands in the west Pacific region. The northern one third of Taiwan is believed to have become occupied only in recent decades (indicated by arrows) **B** a gravid female **C** the eggs. Photographed by Si-Min Lin.

2009) (Fig. 15A). We have no evidence for their impacts on native species, but it is considered likely to compete with native *Gekko* spp., of which the genetic and species diversity is still under-estimated. Currently, most local people (including most biologists) do not yet realize its status as an introduced species; but regardless, eradication of this species from the wild seems impossible.

***Lepidodactylus lugubris* (Dumeril & Bibron, 1836)**

***Hemiphyllodactylus typus* Bleeker, 1860**

***Indotyphlops braminus* (Daudin, 1803)**

Notes. These three small squamates share a common feature: parthenogenesis. They are all regarded as native species in the current literature, and we do not yet have sufficient evidence either to justify, or reject this status. However, the possibility that they are in fact invasive should be reconsidered based on accumulating new lines of evidences.

Lepidodactylus lugubris was first listed as a member of the fauna of Taiwan by Chen's (1984) revised book, but under the name *Gehyra variegata ogasawarasimae* Okada 1930, a junior synonym of *Lepidodactylus lugubris* which was used to refer to the population

of Ogasawara Islands. However, Chen and Yu (1984) did not provide sufficient information for identification or the collection information of this species. Later in 1984, Ota (1986) collected and identified this gecko. Together with *H. frenatus*, *L. lugubris* is regarded as one of the two most globally successful “weedy” geckos (Carranza and Arnold 2006; Behm et al. 2019), invading a wide range especially in insular regions, such as Caribbean islands (Henderson et al. 1976, Kraus 2009, Lorvelec et al. 2011, Lorvelec et al. 2017). Colonization of this species in west Pacific islands was thought to be relevant to the active army traffic since World War II (Hunsacker and Breese 1967, Ineich 1999). The unstoppable expansion is still occurring to new places (Krysko and MacKenzie-Krysko 2016, Lapwong and Juthong 2018, Behm et al. 2019).

Similar to *L. lugubris*, *Hemiphyllodactylus typus* was discovered in central 1980s by Lue et al. (1985). However, it is hard to identify the status of these two geckos prior to this, because the investigation of lizards of Taiwan was scarce until the late 1970s. Not long after these records, Japanese scientists reported the occurrence of both two geckos in southern Ryukyu (200 km east of Taiwan) in the 1990s, and formally treated them as invasive species since the turn of the 21st century (Ota et al. 2004). Yamashiro et al. (2000) investigate the genetic composition of *L. lugubris* from a wide range including Ryukyu, Taito, and Ogasawara islands. In addition to concluding the Ryukyu geckos as invasive populations, they further proposed several ways to distinguish between invasive and native populations of *L. lugubris* by means of karyotype and molecular methods. These guide lines could be applied to study the origin of Taiwanese population in the future.

Another species, for which most local biologists are not yet aware of its status as an introduced species, is the brahminy blind snake (*Indotyphlops braminus*). This parthenogenic snake has been listed in the Global Invasive Species Database (GISD) as an invasive species except for its original habitat in India (Ota et al. 2004, Kraus 2009). GISD also defines *I. braminus* as an alien species in Taiwan. Similar to the previous geckos, the research of the species is scarce in Taiwan.

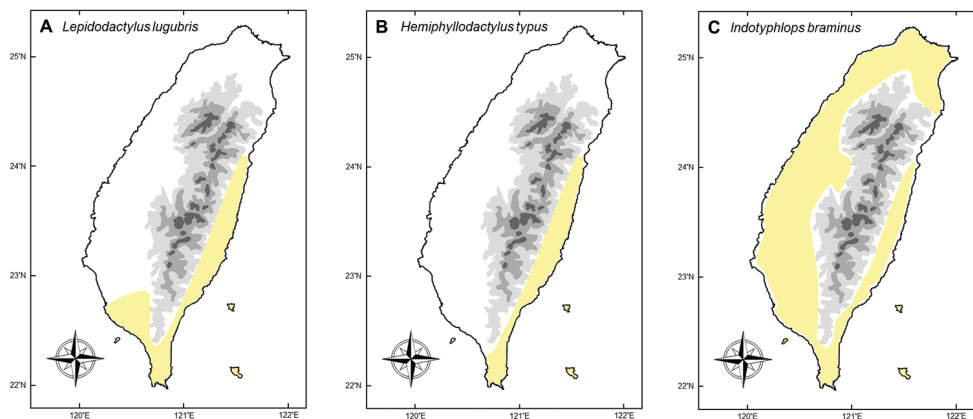


Figure 16. Distributions of *Lepidodactylus lugubris* (A) and *Hemiphyllodactylus typus* (B) are restricted to eastern and southern Taiwan, while *Indotyphlops braminus* (C) is believed to occupy all lowland region of the island.

Currently, the two geckos have wide distributions throughout eastern and southern Taiwan, including Orchid Island and Green Island (Figs 16A, 16B). The blind snake is distributed throughout the low land area of the entire island of Taiwan (Fig. 16C). All the three species have established large populations and would be difficult to eradicate if they are indeed invasive. The controversy of these species, with uncertain origins, is expected to be answered by more comprehensive sampling on a global scale, and with the assistance of more powerful genetic tools in the future.

Other high-risk species

Fourteen species, including three amphibians, four lizards, two snakes, four turtles, and one crocodilian (listed in Table 2) are considered to have a high-risk of invasion into Taiwan in the future.

The cane toad, *Rhinella marina*, might be one of the most notorious invasive anurans in the world. Established populations have spread and expanded to huge population sizes in southern Ryukyu, which is located less than 200 km from eastern Taiwan (Ota et al. 2004). Considering the similar climate, this species has a high potential to invade Taiwan. A similar situation exists for the green anole, *Anolis carolinensis*, which has successfully invaded southern Okinawa, Ogasawara Islands, and Hawaii Islands (Kraus 2009). The third species which represent high invasion risk is *Polypedatus leucomystax*. It has successfully colonized in a wide range throughout Ryukyu Archipelago (Ota et al. 2004). Its congener, *P. megacephalus*, has invaded in Taiwan and caused serious impacts to the native *P. braueri*; while the probable colonization of a third congener might worsen the current situation. Potential invasion of these three species should be considered serious and should be monitored to avoid what could be a serious invasion.

The other species listed in Table 2 are all popular pets in the pet trade. Except for the small salamander *Cynops orientalis*, all species in the list are medium- to large-sized reptiles. Most reported cases are giant lizards or pythons which escape to urban or suburban areas, usually due to improper housing facilities that are not secure enough to house these strong animals. Some of the turtles might be intentionally released because they grow too large to be handled. Escaped individuals of alligator snapping turtle (*Macrochelys temminckii*), common snapping turtle (*Chelydra serpentina*), Asian water monitor (*Varanus salvator*), Nile monitor (*V. niloticus*), and the common caiman (*Caiman crocodilus*) have been found in different drainages by fishermen or tourists; all are believed from human release. The reticulated python (*Malayopython reticulatus*) has been found in rural region for several times, which has raised potential safety concerns. The latest case which caused public panic occurred on 17 January 2019, when a 4.5-m python was killed by train accident in Fangshan township, southern Taiwan. The tissue of this snake has been collected for molecular analysis, which might help to clarify the origin of this individual.

We do not consider these large reptiles to currently form invasive populations in Taiwan, but the disastrous cases of invasive reptiles in Ryukyu, Japan and Florida, USA serve as a useful reminder of the potential invasion risks and catastrophic ecological outcomes.

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A conservation checklist of the amphibians and reptiles of Sonora, Mexico, with updated species lists

Julio A. Lemos-Espinal¹, Geoffrey R. Smith², James C. Rorabaugh³

1 *Laboratorio de Ecología-UBIPRO, FES Iztacala UNAM, Avenida los Barrios 1, Los Reyes Iztacala, Tlalnepantla, edo. de Mexico, 54090, Mexico* **2** *Department of Biology, Denison University, Granville, Ohio 43023, USA* **3** *P.O. Box 31, Saint David, Arizona 85630, USA*

Corresponding author: Julio A. Lemos-Espinal (lemos@unam.mx)

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Abstract

Sonora has a rich natural diversity, including reptiles and amphibians. Sonora's location on the United States-Mexico border creates some unique conservation challenges for its wildlife. We compiled a list of the amphibian and reptile species currently known for Sonora, summarized the conservation status of these species, and compared our list of species with known species lists for adjacent states. The herpetofauna of Sonora comprises 200 species of amphibians and reptiles (38 amphibians and 162 reptiles). Overall, Sonora shares the most species with Chihuahua, Sinaloa, and Arizona. Approximately 11% of the amphibian and reptile species are IUCN listed, but 35.5% are placed in a protected category by SEMARNAT, and 32.6% are categorized as high risk by the Environmental Vulnerability Score.

Keywords

United States-Mexico border states, ecoregions, herpetofauna, IUCN Red List, shared species

Introduction

Sonora is a state that, due to its geographic location near the U.S. states of Arizona and California and the extraordinary natural diversity those states host, has attracted the attention of specialists and amateurs in the study of its flora and fauna. Therefore, Sonora's biodiversity is perhaps the best known among the states of northern Mexico.

Sonora's varied topography and climate (Figs 1, 2); with altitudes ranging from sea level to 2,625 m, broad plains in the west, high mountains in the east, islands in the Gulf of California, and more than 1,200 km of coastline; have resulted in high levels of biodiversity. Sonora is also home to relatively unique habitats, such as the peat moss habitat found in the Ciénega de Camilo in eastern Sonora (Van Devender et al. 2003), and the spring-fed wetlands or ciénegas of the Apache Highlands of Arizona and Sonora (Minckley et al. 2013). Sonora is also part of the main "hot spot" of tropical dry forests; however, climate change is likely to result in degradation of these forests as is deforestation and increased clearing for agriculture (Prieto-Torres et al. 2016).

Given its physiographic and topographic diversity, Sonora is home to high levels of biodiversity, including its herpetofauna (see Lemos-Espinal and Rorabaugh 2015). In particular, Sonora has several areas that are important with respect to herpetofaunal diversity. The desert shrubland in Sonora supports a high diversity of lizards due to the abundance of microhabitats it provides (García and Whalen 2003). Sonora is the location of the southern range limits of several arid adapted reptiles and amphibians (Bezy et al. 2017), but also the location of the northern limits of Neotropical species (Lavín-Murcio and Lazcano 2010). The Northern Jaguar Reserve in Sonora houses a mixture of amphibians and reptiles from a variety of macrohabitat and biogeographic regions (Rorabaugh et al. 2011). The Pacific Lowlands, including areas of Sonora, are one of the more critical areas of endemism for reptiles and amphibians in Mexico (Johnson et al. 2017).

The location of Sonora along the United States-Mexico border creates some unique issues for the conservation of its wildlife. Environmental quality and ecosystem services on the Mexican side of the Sonora-Arizona border are declining (Norman et al. 2012b). One challenge confronting Sonora's environment is human population growth and urbanization. This is particularly important along the U.S.-Mexico border as the human population of Nogales, Mexico is rapidly increasing (Norman et al. 2009, 2012a), which is consistent with a general trend in the border region (Anderson 2003). There has also been an increase in economic growth in Sonora, especially agriculture and ranching (Magaña and Conde 2000). Grazing by cattle can result in the loss of important native vegetation and alteration of Sonoran habitats (Morales-Romero et al. 2012). Such development will potentially result in major losses in habitats, such as riparian woodlands and semi-desert grasslands in the region (Villarreal et al. 2013). Other conservation concerns include non-native species (Bogan et al. 2014, Drake et al. 2017), habitat fragmentation that reduces demographic and genetic connectivity (e.g., across the international border due to construction of walls and other infrastructure on the U.S. side; Peters et al. 2018), and climate change resulting in changes in temperature and precipitation (Stahlschmidt et al. 2011, Flesch et al. 2017, Griffis-Kyle et al. 2018).

Another challenge to Sonora's environment is related to water usage. Watersheds in the region are subject to increasing urbanization, ranching, and losses due to irrigation (Steiner et al. 2000). Increased human populations in Sonora will also drain freshwater for domestic uses and for power generation (Magaña and Conde 2000, Scott et al. 2012). Also, some freshwater systems in Sonora are subject to salinization due to intrusion of saltwater into freshwater aquifers as a result of pumping of water from the aqui-

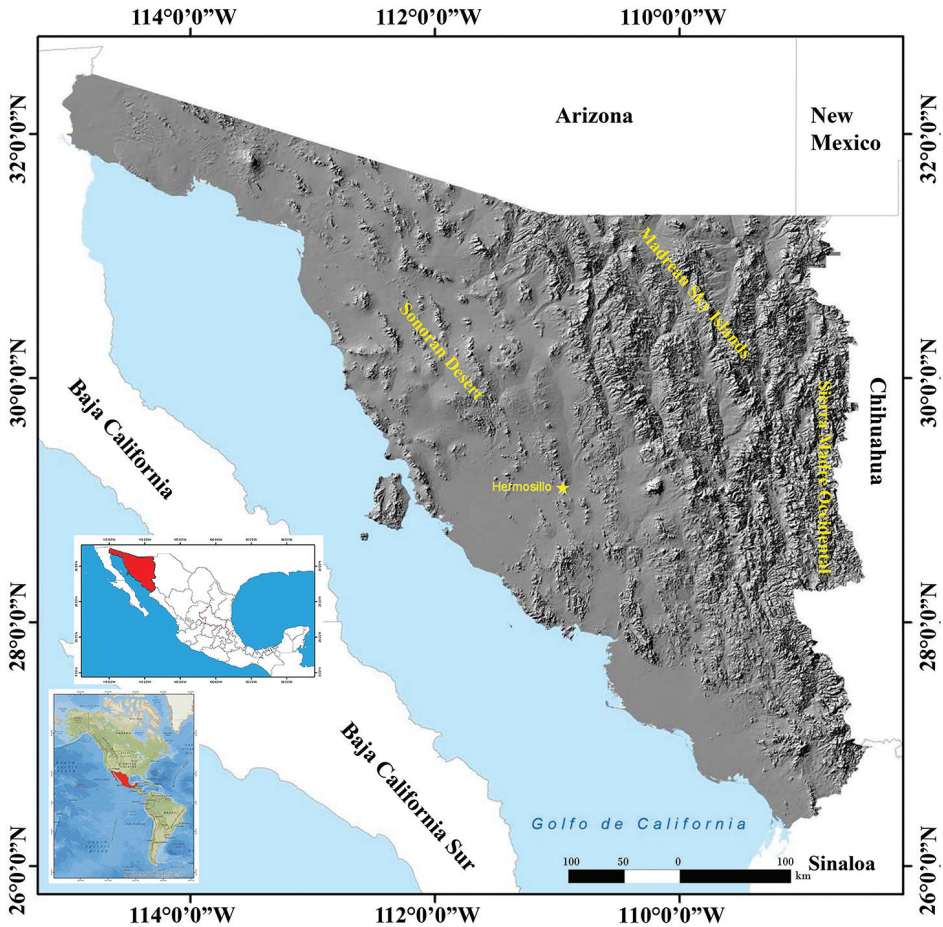


Figure 1. Topographical map of the state of Sonora, Mexico (INEGI 2009). Map of America modified from <http://www.gifex.com/fullsize/2009-09-17-3/Mapa-de-Amrica.html>; Map of Mexico with the state of Sonora in red modified from Comisión Nacional para el Conocimiento y Uso de la Biodiversidad (2008).

fers for human use (Contreras-B. and Lozano-V. 1994, Halvorson et al. 2003). Climate change is also likely to increase the strain on freshwater aquifers in Sonora (Scott et al. 2012) and the region encompassing the US-Mexico border areas (Ye and Grimm 2013).

The factors mentioned above are likely to affect several taxonomic groups, but the herpetofauna is a group of particular concern. Rorabaugh (2008) found that 40% of the Sonoran herpetofauna were given some conservation status by the Mexican government (SEMARNAT) or the IUCN Red List. Although there have been several recent works that report lists of species of reptiles and amphibians in Sonora (Rorabaugh 2008, Enderson et al. 2009, 2010, Lemos-Espinal and Smith 2009, Lemos-Espinal and Rorabaugh 2015, Lemos-Espinal et al. 2015, Rorabaugh and Lemos-Espinal 2016), species additions and accelerating taxonomic changes merit a new analysis of the current list for Sonora, especially with respect to the conservation status of the species listed. Here,

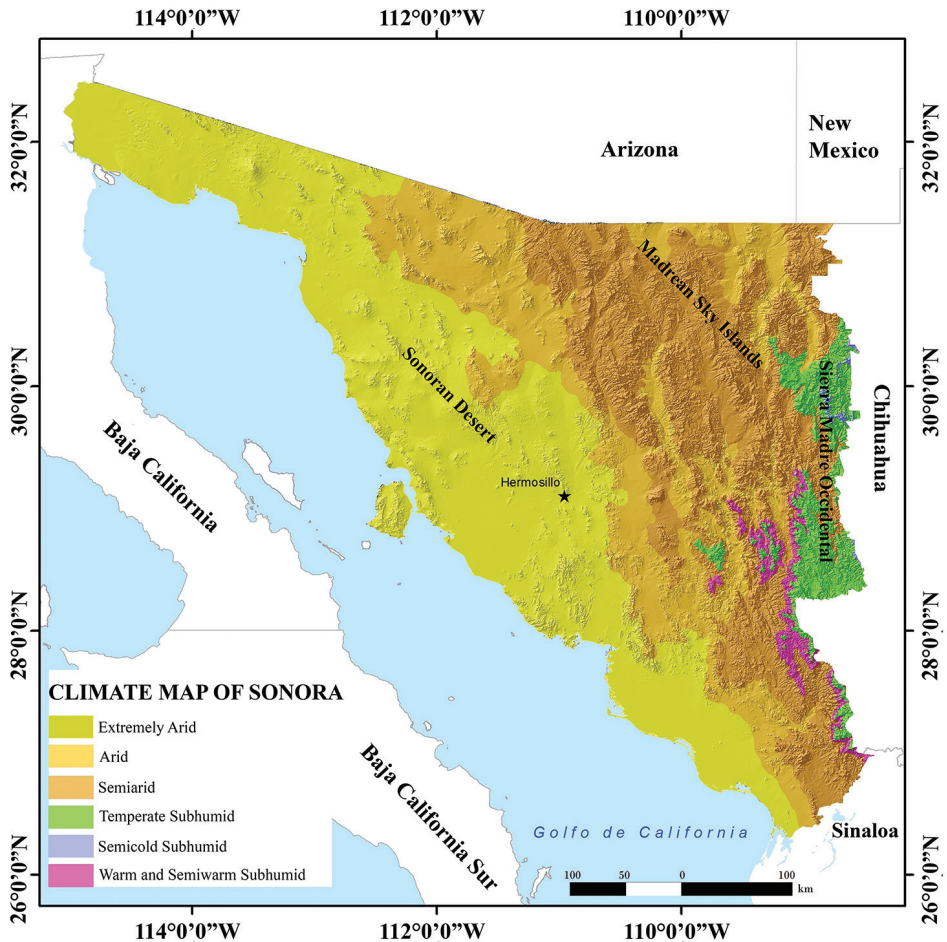


Figure 2. Climate map of the state of Sonora, Mexico (modified from García – CONABIO 1998).

we report the list of species currently known for the state of Sonora, focusing on the conservation status reported for each species, analyzing it by taxonomic groups and ecoregions, and comparing our list of species with known lists for adjacent states.

Methods

We only included species in the checklist for which we could confirm the record in Sonora, either by direct observation or through documented museum records or vouchers. We follow Frost (2018) or AmphibiaWeb (2018) for amphibian names and Uetz and Hošek (2018) for reptile names (for a summary of recent taxonomic changes see Table 1). We compiled the list of amphibians and reptiles of the state of Sonora from

Table 1. Recent taxonomic changes for the herpetofauna of Sonora.

Taxon	Explanation
<i>Rhinella horribilis</i>	Acevedo et al. (2016) demonstrated that there were two separate evolutionary lineages within <i>Rhinella marina</i> representing two distinct species: <i>R. marina</i> for the eastern populations, and <i>R. horribilis</i> for the western populations.
<i>Dryophytes</i>	We use <i>Dryophytes</i> based on Duellman et al. (2016).
<i>Rana</i>	Frost et al. (2006) recommended the use of the name <i>Lithobates</i> for North American <i>Rana</i> . However, we use <i>Rana</i> because Yuan et al. (2016) recently returned all <i>Lithobates</i> to <i>Rana</i> , based on a phylogenetic analysis of six nuclear and three mitochondrial loci sampled from most species of <i>Rana</i> , the lack of any diagnostic morphological characters for the genera recognized by Frost et al. (2006), and the clear monophyly of a larger group that include these genera.
<i>Isthmura sierraoccidentalis</i>	Originally <i>Isthmura sierraoccidentalis</i> was described as a subspecies of <i>Pseudoeurycea belli</i> by Lowe et al. (1968), recently it was elevated to full species status by Rovito et al. (2015).
<i>Aspidoscelis</i>	Tucker et al. (2016), based on Steyskal (1971), explained and justified why the genus name <i>Aspidoscelis</i> should be treated as masculine, thus we use the appropriate masculine species names.
<i>Boa</i>	Card et al. (2016) recently recognized the <i>Boa</i> populations from the slopes of the Mexican Pacific as <i>Boa sigma</i> , which we follow.
<i>Chionactis annulata</i>	Wood et al. (2014) raised <i>Chionactis occipitalis annulata</i> to full species status (<i>C. annulata</i>).
<i>Chionactis</i> , <i>Chilomeniscus</i> , and <i>Sonora</i>	Cox et al. (2018) concluded that <i>Sonora</i> is paraphyletic with respect to <i>Chilomeniscus</i> and <i>Chionactis</i> and found additional evidence to suggest synonymizing <i>Chionactis</i> and <i>Chilomeniscus</i> with <i>Sonora</i> . However, due to the long history of the use of the names of these three genera, we retain the use of the three genera to reduce confusion. In addition, other interpretations of the work of Cox et al. (2018) leave the current arrangement in place instead of synonymizing them (A Holycross and D Wood pers. comm.).
<i>Lampropeltis</i>	Based on the work of Krysko et al. (2017) the state of Sonora hosts three species of the <i>Lampropeltis getula</i> complex: <i>Lampropeltis californiae</i> along most of the border with Arizona; <i>Lampropeltis splendida</i> in the northeastern corner of the state, in the region where Arizona, New Mexico, Chihuahua and Sonora converge; and <i>Lampropeltis nigrita</i> , occupying most of the state of Sonora, including the islands of Tiburón and San Pedro Nolasco.
<i>Crotalus pyrrhus</i>	Meik et al. (2015) elevated <i>Crotalus mitchelli pyrrhus</i> to full species status, so we report <i>C. pyrrhus</i> as occurring in Sonora.

the following sources: (1) our own field work; (2) specimens from the Amphibians and Reptiles collection of the University of Arizona; (3) specimens from the Laboratorio de Ecología – UBIPRO (LEUBIPRO) collections; (4) a thorough examination of the available literature on amphibians and reptiles in the state; (5) amphibian and reptile records for the state of Sonora in VertNet.org; and (6) databases from the Comisión Nacional para el Conocimiento y Uso de la Biodiversidad (CONABIO, or National Commission for the Understanding and Use of Biodiversity) (see Appendix 1).

We recognize six herpetological ecoregions in Sonora (Eastern Mountains, High Northeastern Valleys, Western Mainland Deserts, Subtropical Lowlands and Foothills of the Sierra Madre Occidental, Islands, and Marine), each of which supports distinctive amphibian and reptile assemblages (Fig. 3). These ecoregions are further defined by geography, elevational range, topography, and vegetation communities (see Lemos-Espinal and Rorabaugh 2015; Lemos-Espinal et al. 2015; Rorabaugh and Lemos-Espinal 2016 for a description of these ecoregions). As a result, boundaries of ecoregions bear some resemblance to those of physiographic units (Fig. 4) and vegetation communities (Fig. 5).

We recorded the conservation status of each species based on 1) the IUCN Red List 2018-2; 2) Environmental Viability Scores from Wilson et al. (2013a, b); and 3) listing in

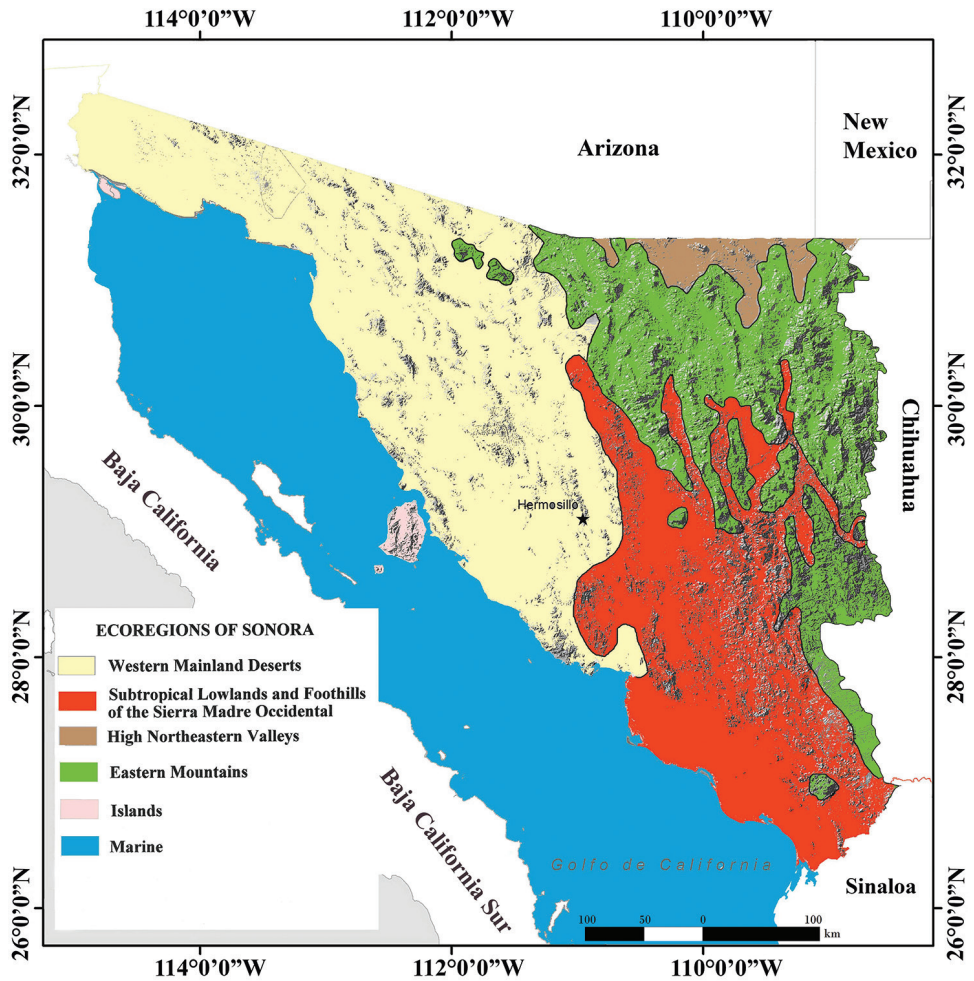


Figure 3. Map of the ecoregions of the state of Sonora, Mexico (created by J Rorabaugh using the base topographic map of INEGI 2009).

SEMARNAT (2010). The number of overlapping species with the five neighboring states of Sonora was determined using recent state lists (Arizona, Brennan and Babb [2015]; Baja California, Hollingsworth et al. [2015]; Sinaloa, Enderson et al. [2009]; Chihuahua, Lemos-Espinal et al. [2017]; and New Mexico, Painter and Stuart [2015]). Lists were updated for Arizona (adding *Lampropeltis californiae* [Blainville] and *L. nigrita* Zweifel & Norris, and substituting *Lampropeltis splendida* [Baird & Girard] for *L. getula* Linnaeus [Krysko et al. 2017]); Baja California (substituting *Lampropeltis californiae* [Blainville] for *L. getula* Linnaeus [Krysko et al. 2017]); Sinaloa (adding *Crocodylus acutus* Cuvier [Natural History Museum of Los Angeles County. LACM Vertebrate Collection. Record ID: D411FDF6-C9FA-471B-BC83-B1FC044E54C3. Source: http://ipt.vertnet.org:8080/ipt/resource.do?r=lacm_verts [accessed on 2018-03-13]], *Leptodeira splendida*

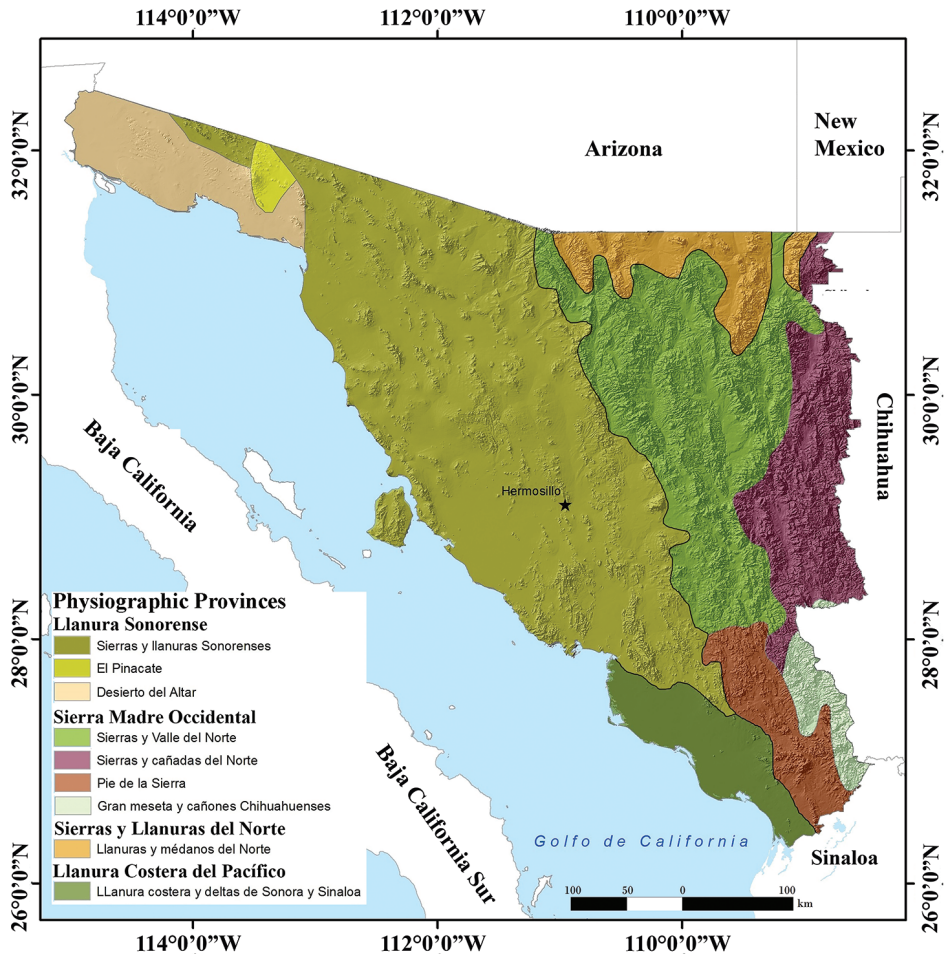


Figure 4. Topographical map with physiographic provinces of the state of Sonora, Mexico. Map modified from Cervantes-Zamora et al. (1990).

Günther [Natural History Museum of Los Angeles County. LACM Vertebrate Collection. Record ID: 6CD2EBCD-71BA-426B-A9A2-9DF8FE3222B5. Source: http://ipt.vertnet.org:8080/ipt/resource.do?r=lacm_verts (accessed on 2018-03-13)], and *Gopherus evgoodei*, Edwards et al. 2016, and substituting *Lampropeltis nigrata* Zweifel & Norris for *L. getula* Linnaeus [Krysko et al. 2017]); Chihuahua (substituting *Sceloporus cowlesi* Lowe & Norris for *S. consobrinus* Baird & Girard [A Leaché, pers. comm., April 2017]); and New Mexico (adding *Lampropeltis holbrooki* Stejneger, and substituting *Lampropeltis splendida* [Baird & Girard] for *L. getula* Linnaeus [Krysko et al. 2017]).

We created species accumulation curves for the total herpetofauna, amphibians, and reptiles using the year of the first recorded observation for each species. Such species accumulation curves are likely to be reasonable estimates of the species richness of amphibians and reptiles (see Raxworthy et al. 2012).

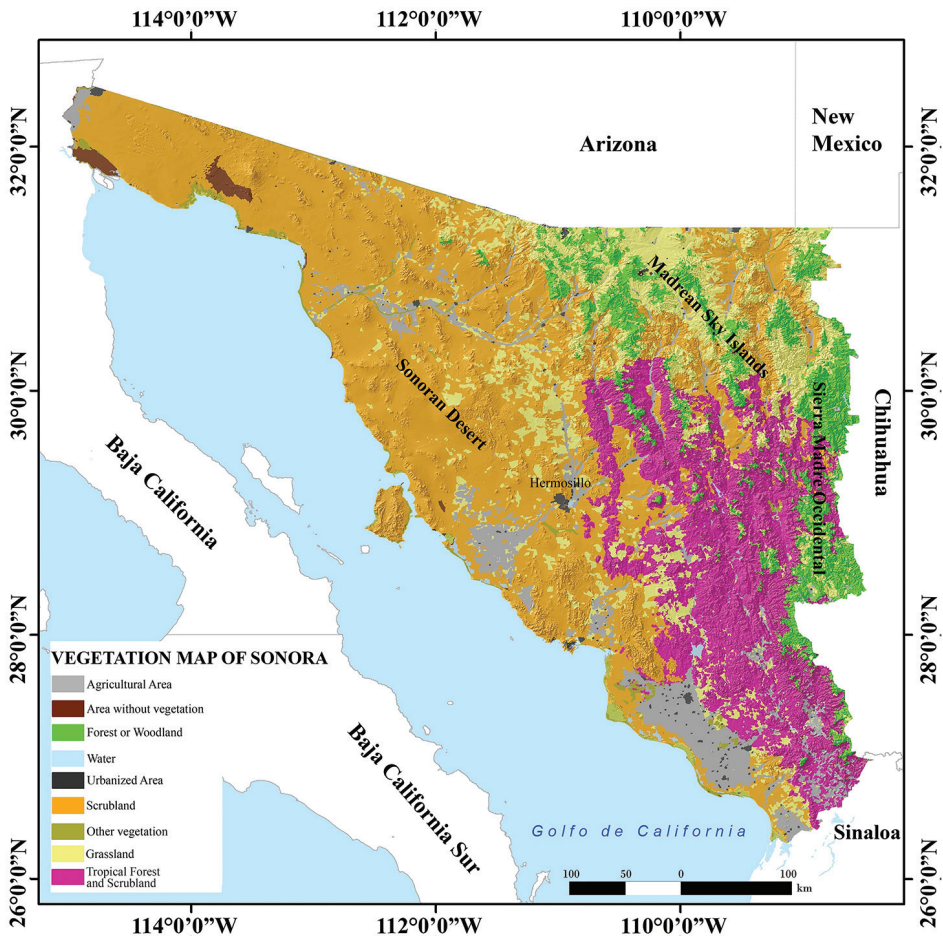


Figure 5. Vegetation type map of the state of Sonora, Mexico (modified from Dirección General de Geografía – INEGI 2005).

Results and discussion

Sonora hosts a total of 200 (seven of them introduced) species of amphibians and reptiles. This is an increase of four species from the list compiled by Rorabaugh and Lemos-Espinal (2016), and 13 species from the list compiled by Enderson et al. (2009). Thirty-eight are amphibians (35 anurans [two introduced], and three salamanders) and 162 reptiles (one crocodile, 69 lizards [three introduced], 75 snakes [one introduced], and 17 turtles [one introduced]) (Tables 2, 3). These represent 38 families: ten amphibians (eight anurans, one salamanders), and 28 reptiles (one crocodile, 12 lizards [one introduced], eight snakes [one introduced], and seven turtles [one introduced]). Sonora has 91 genera: 17 amphibians (15 anurans, two salamanders), and 74 reptiles (one crocodile, 22 lizards [one introduced], 40 snakes [one introduced], and eleven turtles [one

introduced]). Twelve of the 193 native species are only found in islands in Sonora, those are: Isla San Esteban Spiny-tailed Iguana (*Ctenosaura conspicuosa*), Isla San Pedro Nolasco Spiny-tailed Iguana (*C. nolascoensis*), Piebald Chuckwalla (*Sauromalus varius*), Isla San Pedro Nolasco Lizard (*Uta nolascoensis*), Isla San Pedro Mártir Side-blotched Lizard (*U. palmeri*), Peninsular Leaf-toed Gecko (*Phyllodactylus nocticolus*), San Pedro Nolasco Gecko (*P. nolascoensis*), San Pedro Nolasco Whiptail (*Aspidoscelis bacatus*), San Esteban Whiptail (*A. estebanensis*), San Pedro Mártir Whiptail (*A. martyris*), Isla San Esteban Whipsnake (*Masticophis slevini*), and Isla San Esteban Black-tailed Rattlesnake (*Crotalus estebanensis*). Another seven are marine species: American Crocodile (*Crocodylus acutus*), Yellow-bellied Seasnake (*Hydrophis platurus*), Loggerhead Sea Turtle (*Caretta caretta*), Green Sea Turtle (*Chelonia mydas*), Hawksbill Sea Turtle (*Eretmochelys imbricata*), Olive Ridley Sea Turtle (*Lepidochelys olivacea*), and Leatherback Sea Turtle (*Dermochelys coriacea*). The introduced species are: Rio Grande Leopard Frog (*Rana berlandieri*), American Bullfrog (*R. catesbeiana*), Common House Gecko (*Hemidactylus frenatus*), Mediterranean House Gecko (*H. turcicus*), Spiny Chuckwalla (*Sauromalus hispidus*), Brahminy Blindsnake (*Indotyphlops braminus*), and Spiny Softshell (*Apalone spinifera*).

The species accumulation curves for all species, amphibians only, and reptiles only suggest that the current list of species likely underestimates the species richness for Sonora (Fig. 6). These curves show a rapid increase in species during the first half of the 20th century with a steady, almost linear, increase in the number of species recorded in Sonora. Following a brief period of little additional accumulation of new species recorded in Sonora in the late 1900's, there has been a recent increase in the number of species added to the Sonoran herpetofauna. This increase includes recent documentation of non-native species (*Apalone spinifera*, *Hemidactylus frenatus*, and *H. turcicus*), as well as recent taxonomic changes (see Table 1).

We compiled a list of 17 species (three amphibians, 14 reptiles) potentially occurring in Sonora (Table 4) based on species for which undocumented observations in Sonora exist but for which museum or other records are not available, and on species that have not been recorded or observed in the state, but whose distributional ranges come close to the borders of Sonora. We did not include these species in our analyses and summaries.

General distribution

Fourteen of the 38 species of amphibians that inhabit Sonora are endemic to Mexico, one of which is restricted to small areas in the Sierra Madre Occidental in eastern Sonora and western Chihuahua (Table 2). Four more are distributed in the Sierra Madre Occidental mainly in the states of Chihuahua, Durango, Sinaloa, and Sonora (Table 2). Another six species are distributed along the Pacific coast, and three more along the Pacific coast extending eastward through the Balsas depression, with one of these three even reaching the state of Veracruz (Table 2). Of the 24 amphibian species not endemic to Mexico that inhabit Sonora, two are introduced species, 17 more are found in the US and Mexico, and the remaining five species have a wide distribution

Table 2. Amphibians and reptiles of Sonora with distributional and conservation status. Ecoregion (1 = Western mainland deserts; 2 = High northeastern valleys; 3 = Eastern mountains; 4 = Subtropical lowlands and foothills; 5 = Marine; 6 = Islands); IUCN Status (DD = Data Deficient; LC = Least Concern, VU = Vulnerable, NT = Near Threatened; EN = Endangered; CE = Critically Endangered; NE = not Evaluated) according to the IUCN Red List (The IUCN Red List of Threatened Species, Version 2018-1; www.iucnredlist.org; accessed 14 September 2018), conservation status in Mexico according to SEMARNAT (2010) (P = in danger of extinction, A = threatened; Pr = subject to special protection, NL – not listed), and Environmental Vulnerability Score (EVS – the higher the score the greater the vulnerability: low (L) vulnerability species (EVS of 3–9); medium (M) vulnerability species (EVS of 10–13); and high (H) vulnerability species (EVS of 14–20) from Wilson et al. (2013a,b) and Johnson et al. (2015). Global Distribution (GD): 0 = Endemic to Sonora; 1 = Endemic to Mexico; 2 = Shared between the US and Mexico; 3 = widely distributed from Canada or the US to Central or South America; 4 = widely distributed from Mexico to Central America; 5 = circumglobal distribution; 6 = Pacific and Indian Oceans; IN = Introduced to Sonora. Source of first record (year in parentheses) is the voucher specimen (see Appendix 1 for abbreviations) or paper associated with the first documentation of a species in Sonora.

	IUCN	EVS	SEMARNAT	Ecoregions	GD	Source of first record
Class Amphibia						
Order Anura						
Bufonidae						
<i>Anaxyrus cognatus</i> (Say, 1823)	LC	L (8)	NL	1, 2	2	UAZ 08894 (1957)
<i>Anaxyrus debilis</i> (Girard, 1854)	LC	L (7)	Pr	2	2	UAZ 40063 (1974)
<i>Anaxyrus kelloggi</i> (Taylor, 1938)	LC	H (14)	NL	1, 4	1	UTEP H-14419 (1955)
<i>Anaxyrus mexicanus</i> (Brocchi, 1879)	NT	M (13)	NL	3	1	UAZ 15045 (1953)
<i>Anaxyrus punctatus</i> (Baird & Girard, 1852)	LC	L (5)	NL	1, 2, 3, 4, 6	2	UAZ 16973 (1905)
<i>Anaxyrus retiformis</i> (Sanders & Smith, 1951)	LC	M (12)	Pr	1	2	MCZ A-48217 (1700)
<i>Anaxyrus woodhousii</i> (Girard, 1854)	LC	M (10)	NL	1, 2	2	USNM 2536 (1855)
<i>Incilius alvarius</i> (Girard, 1859)	LC	M (11)	NL	1, 2, 3, 4	2	USNM 21063 (1893)
<i>Incilius marmoreus</i> (Wiegmann, 1833)	LC	M (11)	NL	4	1	UAZ 57334-PSV (2011)
<i>Incilius mazatlanensis</i> (Taylor, 1940)	LC	M (12)	NL	1, 2, 3, 4	1	UAZ 11817 (1953)
<i>Incilius mcooyi</i> Santos-Barrera & Flores-Villela, 2011	NE	H (14)	NL	3	1	UAZ 28229 (1964)
<i>Rhinella horribilis</i> (Wiegmann, 1833)	NE	NE	NL	1, 4	3	USNM 47243 (1898)
Craugastoridae						
<i>Craugastor augusti</i> (Dugès, 1879)	LC	L (8)	NL	3, 4	2	USNM311989 (1921)
<i>Craugastor occidentalis</i> (Taylor, 1941)	DD	M (13)	NL	3, 4	1	AMNH A-84437 (1970)
<i>Craugastor tarahumaraensis</i> (Taylor, 1940)	VU	H (17)	Pr	3	1	UAZ 28133 (1968)
Eleutherodactylidae						
<i>Eleutherodactylus interorbitalis</i> (Langebartel & Shannon, 1956)	DD	H (15)	Pr	3, 4	1	UAZ 56549-PSV (2005)
Hylidae						
<i>Agalychnis dacnicolor</i> (Cope, 1864)	LC	M (13)	NL	3, 4	1	LACM 90158 (1960)
<i>Dryophytes arenicolor</i> Cope, 1886	LC	L (7)	NL	2, 3, 4	2	MVZ 28776 (1939)
<i>Dryophytes wrightorum</i> (Taylor, 1939)	LC	L (9)	NL	2, 3	2	BYU 34818 (1979)
<i>Smilisca baudinii</i> (Duméril & Bibron, 1841)	LC	L (3)	NL	4	3	MVZ 50460 (1950)
<i>Smilisca fodiens</i> (Boulenger, 1882)	LC	L (8)	NL	1, 4	2	UMMZ 72186 (1932)
<i>Tlalocohyla smithii</i> (Boulenger, 1902)	LC	M (11)	NL	1, 4	1	UAZ 16066 (1956)
Leptodactylidae						
<i>Leptodactylus melanonotus</i> (Hallowell, 1861)	LC	L (6)	NL	1, 2, 4	4	MVZ 26066 (1938)
Microhylidae						
<i>Gastrophryne mazatlanensis</i> (Taylor, 1943)	NE	L (8)	NL	1, 3, 4	2	UMMZ 72177 (1932)
<i>Hypopachus variolosus</i> (Cope, 1866)	LC	L (4)	NL	4	3	UAZ 47259 (1938)
Ranidae						
<i>Rana berlandieri</i> Baird, 1859	N/A	N/A	N/A	N/A	IN	ASU HP-00020-21 (2006)

	IUCN	EVS	SEMARNAT	Ecoregions	GD	Source of first record
<i>Rana catesbeiana</i> Shaw, 1802	N/A	N/A	N/A	N/A	IN	CAS SUA 202273 (1955)
<i>Rana chiricahuensis</i> Platz & Mecham, 1979	VU	M (11)	A	2, 3	2	LACM 91589 (1965)
<i>Rana forreri</i> Boulenger, 1883	LC	L (3)	Pr	1, 4	4	KUH 37904 (1954)
<i>Rana magnaocularis</i> Frost & Bagnara, 1976	LC	M (12)	NL	1, 2, 3, 4	1	CAS SUA 15580 (1955)
<i>Rana pustulosa</i> Boulenger, 1883	LC	L (3)	Pr	4	1	ASNNHC 13774 (1969)
<i>Rana tarahumarae</i> Boulenger, 1917	VU	L (8)	NL	3	2	UMMZ 154302 (1935)
<i>Rana yavapaiensis</i> Platz & Frost, 1984	LC	M (12)	Pr	1, 3, 4	2	CAS SUA 10295 (1950)
Scaphiopodidae						
<i>Scaphiopus couchi</i> Baird, 1854	LC	L (3)	NL	1, 2, 3, 4	2	Allen, 1933 (1932)
<i>Spea multiplicata</i> (Cope, 1863)	LC	L (6)	NL	1, 2, 3	2	USNM 21801 (1894)
Order Caudata						
Ambystomatidae						
<i>Ambystoma marvortium</i> Baird, 1850	LC	M (10)	NL	1, 2	2	UMMZ 78353 (1935)
<i>Ambystoma rosaceum</i> Taylor, 1941	LC	H (14)	Pr	3	1	USNM 17352 (1891)
Plethodontidae						
<i>Isthmura sierraoccidentalis</i> (Lowe, Jones, & Wright, 1968)	NE	NE	NL	3	1	LACM 39200 (1964)
Class Reptilia						
Order Crocodylia						
Crocodylidae						
<i>Crocodylus acutus</i> Cuvier, 1807	VU	H (14)	Pr	5	3	PBDB 20495 (1764)
Order Squamata						
Suborder Lacertilia						
Anguidae						
<i>Elgaria kingii</i> Gray, 1838	LC	M (10)	Pr	2, 3	2	UAZ 07265 (1905)
Crotaphytidae						
<i>Crotaphytus collaris</i> (Say, 1823)	LC	M (13)	A	2, 3	2	CAS HERP 3411 (1892)
<i>Crotaphytus dickersonae</i> Schmidt, 1922	LC	H (16)	NL	1, 6	0	CAS HERP 53264 (1921)
<i>Crotaphytus nebrinus</i> Axtell & Montanucci, 1977	LC	M (12)	NL	1, 3	2	MVZ 10164 (1926)
<i>Gambelia wislizenii</i> (Baird & Girard, 1852)	LC	M (13)	Pr	1, 2	2	USNM 43183 (1910)
Dactyloidae						
<i>Anolis nebulosus</i> (Wiegmann, 1834)	LC	M (13)	NL	3, 4	1	MVZ 84691 (1818)
Eublepharidae						
<i>Coleonyx fasciatus</i> (Boulenger, 1885)	LC	H (17)	NL	3, 4	1	UAZ 01186 (1958)
<i>Coleonyx variegatus</i> (Baird, 1858)	LC	M (11)	Pr	1, 2, 4	2	UCM 58228 (1800)
Gekkonidae (Introduced)						
<i>Hemidactylus frenatus</i> Schlegel, 1836	N/A	N/A	N/A	N/A	IN	UABC 1728 (2007)
<i>Hemidactylus turcicus</i> (Linnaeus, 1758)	N/A	N/A	N/A	N/A	IN	UAZ 56726-PSV (2007)
Helodermatidae						
<i>Heloderma exasperatum</i> Bogert and Martín del Campo, 1856	NE	NE	NL	3, 4	1	LACM 62549 (1942)
<i>Heloderma suspectum</i> Cope, 1869	NT	H (15)	A	1, 2, 3, 4	2	USNM 20998 (1893)
Iguanidae						
<i>Ctenosaura conspicuosa</i> Dickerson, 1919	NE	H (16)	NL	6	0	CAS HERP 55034 (1912)
<i>Ctenosaura macrolopha</i> Smith, 1972	NE	H (19)	NL	1, 3, 4	1	SDNHM 3859 (1930)
<i>Ctenosaura nolascentis</i> Smith, 1972	VU	H (17)	NL	6	0	CAS HERP 50562 (1921)
<i>Dipsosaurus dorsalis</i> (Baird & Girard, 1852)	LC	M (11)	NL	1	2	MVZ 20843 (1936)
<i>Sauromalus ater</i> Duméril, 1856	LC	M (13)	Pr	1	2	USNM 13483 (1883)
<i>Sauromalus hispidus</i> Stejneger, 1891	N/A	N/A	N/A	N/A	IN	CAS HERP 104443 (1967)
<i>Sauromalus varius</i> Dickerson, 1919	NE	H (16)	A	6	10	USNM 64441 (1911)
Phrynosomatidae						
<i>Callisaurus draconoides</i> Blainville, 1835	LC	M (12)	A	1, 4	2	CAS HERP 55037 (1911)
<i>Cophosaurus texanus</i> Troschel, 1852	LC	H (14)	A	1, 2, 3	2	CAS SUR 9882 (1942)
<i>Holbrookia approximans</i> Baird, 1859	NE	H (14)	NL	1	1	UCM 58250 (1800)
<i>Holbrookia elegans</i> Bocourt, 1874	LC	M (13)	NL	1, 2, 3, 4	2	MCZ R-641 (1859)
<i>Phrynosoma cornutum</i> (Harlan, 1825)	LC	M (11)	NL	2	2	MVZ 38192 (1818)
<i>Phrynosoma ditmarsii</i> Stejneger, 1906	DD	H (16)	NL	3	0	USNM 36013 (1897)

	IUCN	EVS	SEMARNAT	Ecoregions	GD	Source of first record
<i>Phrynosoma goodei</i> Stejneger, 1893	NE	M (13)	NL	1	2	CM S4812 (1928)
<i>Phrynosoma hernandesi</i> Girard, 1858	LC	M (13)	NL	2, 3	2	USNM 21022 (1893)
<i>Phrynosoma mcallii</i> (Hallowell, 1852)	NT	H (15)	A	1	2	USNM 21841 (1894)
<i>Phrynosoma modestum</i> Girard, 1852	LC	M (12)	NL	2	2	USNM 21021 (1893)
<i>Phrynosoma orbiculare</i> (Linnaeus, 1766)	LC	M (12)	A	3	1	MCZ R-169820 (1700)
<i>Phrynosoma solare</i> Gray, 1845	LC	H (14)	NL	1, 2, 3, 4, 6	2	UAZ 02189 (1905)
<i>Sceloporus albiventris</i> Smith, 1939	NE	H (16)	NL	3, 4	1	BYU 21179 (1961)
<i>Sceloporus clarkii</i> Baird & Girard, 1852	LC	M (10)	NL	1, 2, 3, 4, 6	2	CAS HERP 50516 (1921)
<i>Sceloporus cowlesi</i> Lowe & Norris, 1956	NE	M (13)	NL	2	2	UAZ 36545 (1973)
<i>Sceloporus jarrovi</i> Cope, 1875	NE	M (11)	NL	3	2	USNM 17252 (1891)
<i>Sceloporus lemosespinali</i> Lara-Góngora, 2004	DD	H (16)	NL	3	1	UAZ 16588 (1966)
<i>Sceloporus magister</i> Hallowell, 1854	LC	L (9)	NL	1	2	CAS HERP 53359 (1921)
<i>Sceloporus nelsoni</i> Cochran, 1923	LC	M (13)	NL	3, 4	1	MVZ 28914 (1939)
<i>Sceloporus poinsettii</i> Baird & Girard, 1852	LC	M (12)	NL	3	2	USNM 313440 (1921)
<i>Sceloporus slevini</i> Smith, 1937	LC	M (11)	NL	2, 3	2	UAZ 02914 (1953)
<i>Sceloporus virgatus</i> Smith, 1938	LC	H (15)	NL	3	2	MCZ R-46525 (1933)
<i>Uma rufopunctata</i> Cope, 1895	NT	H (16)	NL	1	2	CAS HERP 53368 (1921)
<i>Urosaurus bicarinatus</i> (Duméril, 1856)	LC	M (12)	NL	4	1	MVZ 28889 (1939)
<i>Urosaurus graciosus</i> Hallowell, 1854	LC	H (14)	NL	1	2	MVZ 10160 (1926)
<i>Urosaurus ornatus</i> (Baird & Girard, 1852)	LC	M (10)	NL	1, 2, 3, 4, 6	2	CAS HERP 53257 (1921)
<i>Uta nolasensis</i> Van Denburgh & Slevin, 1921	LC	H (17)	A	6	0	CAS HERP 50539 (1921)
<i>Uta palmeri</i> Stejneger, 1890	VU	H (17)	A	6	0	CAS HERP 50580 (1921)
<i>Uta stansburiana</i> Baird & Girard, 1852	LC	M (11)	A	1, 6	2	CAS HERP 50705 (1921)
Phyllodactylidae						
<i>Phyllodactylus homolepidurus</i> Smith, 1935	LC	H (15)	Pr	1, 4	1	CMNH 13022 (1932)
<i>Phyllodactylus nocticolus</i> Dixon, 1964	NE	M (10)	NL	6	2	CAS HERP 50798 (1921)
<i>Phyllodactylus nolascoensis</i> Dixon, 1964	NE	NE	NL	6	0	CAS HERP 50550 (1921)
<i>Phyllodactylus tuberculosus</i> Wiegmann, 1835	LC	L (8)	NL	4	4	KUH 24117 (1948)
Scincidae						
<i>Plestiodon callicephalus</i> (Bocourt, 1879)	LC	M (12)	NL	3	2	UAZ 03469 (1905)
<i>Plestiodon obsoletus</i> (Baird & Girard, 1852)	LC	M (11)	NL	1, 3	2	UAZ 35168 (1972)
<i>Plestiodon parvauriculatus</i> (Taylor, 1933)	DD	H (15)	Pr	3, 4	1	USNM 47536 (1899)
Teiidae						
<i>Aspidoscelis bacatus</i> (Van Denburgh & Slevin, 1921)	LC	H (17)	Pr	6	0	Van Denburgh and Slevin 1921 (1921)
<i>Aspidoscelis burti</i> (Taylor, 1938)	LC	H (15)	NL	1	0	CAS HERP 53425 (1921)
<i>Aspidoscelis costatus</i> (Cope, 1878)	NE	M (11)	Pr	1, 3, 4	1	MVZ 28921 (1939)
<i>Aspidoscelis estebanensis</i> (Dickerson, 1919)	NE	NE	Pr	6	0	Dickerson, 1919 (1919)
<i>Aspidoscelis exsanguis</i> (Lowe, 1956)	LC	H (14)	NL	3	2	MVZ 21018 (1936)
<i>Aspidoscelis martyris</i> (Stejneger, 1891)	VU	H (17)	Pr	6	0	Stejneger, 1891 (1891)
<i>Aspidoscelis opatae</i> (Wright, 1967)	DD	H (16)	NL	3	0	UAZ 09228 (1963)
<i>Aspidoscelis sonora</i> (Lowe & Wright, 1964)	LC	M (13)	NL	1, 2, 3	2	UAZ 05045 (1905)
<i>Aspidoscelis stictogrammus</i> (Burger, 1950)	NE	H (14)	NL	1, 3	2	USNM 15752 (1889)
<i>Aspidoscelis tigris</i> (Baird & Girard, 1852)	LC	L (8)	NL	1	2	CAS HERP 49152 (1921)
<i>Aspidoscelis uniparens</i> (Wright & Lowe, 1965)	LC	H (15)	NL	2	2	UAZ 05125 (1905)
<i>Aspidoscelis xanthonotus</i> (Duellman & Lowe, 1953)	NE	H (14)	NL	1	2	Rosen and Quijada-Mascareñas 2009 (2009)
Xantusiidae						
<i>Xantusia jaycolei</i> Bezy, Bezy, & Bolles, 2009	NE	H (16)	NL	1	0	UAZ 10760 (1964)
<i>Xantusia vigilis</i> Baird, 1859	LC	NE	NL	1	2	CAS HERP 84144 (1949)
Suborder Serpentes						
Boidae						
<i>Boa sigma</i> Smith, 1943	NE	NE	NL	1, 3, 4	1	USNM 61956 (1887)
<i>Lichanura trivirgata</i> Cope, 1861	LC	M (10)	A	1	2	SDNHM 10793 (1933)

	IUCN	EVS	SEMARNAT	Ecoregions	GD	Source of first record
Colubridae						
<i>Arizona elegans</i> Kennicott, 1859	LC	L (5)	NL	1	2	SDNHM 16479 (1934)
<i>Chilomeniscus stramineus</i> Cope, 1860	LC	L (8)	Pr	1, 6	2	UAZ 23194 (1958)
<i>Chionactis annulata</i> (Baird, 1858)	LC	M (12)	NL	1	2	CUMV 1243 (1930)
<i>Chionactis palmarostris</i> (Klauber, 1937)	LC	M (13)	NL	1	2	MCZ R-36890 (1932)
<i>Drymarchon melanurus</i> (Duméril, Bibron & Duméril, 1854)	LC	L (6)	NL	1, 3, 4	3	
<i>Drymobius margaritiferus</i> (Schlegel, 1837)	NE	L (6)	NL	4	3	MVZ 28930 (1939)
<i>Gyalopion canum</i> Cope, 1861	LC	L (9)	NL	2, 3	2	UAZ 20736 (1954)
<i>Gyalopion quadrangulare</i> (Günther, 1893)	LC	M (11)	Pr	1, 4	2	KUH 24113 (1948)
<i>Lampropeltis californiae</i> (Blainville, 1835)	NE	M (10)	NL	1	2	UAZ 25105 (1905)
<i>Lampropeltis knoblochi</i> Taylor, 1940	NE	M (10)	NL	3	2	SDNHM 41106 (1950)
<i>Lampropeltis nigrita</i> Zweifel & Norris, 1955	NE	NE	NL	1, 2, 3, 4, 6	2	USNM 21720 (1894)
<i>Lampropeltis polyzona</i> Cope, 1860	NE	L (7)	NL	3, 4	1	MVZ 50813 (1950)
<i>Lampropeltis splendida</i> (Baird & Girard, 1853)	NE	M (12)	NL	2, 3	2	Baird and Girard 1853 (1853)
<i>Leptophis diplotropis</i> (Günther, 1872)	LC	H (14)	A	3, 4	1	SDNHM 18176 (1947)
<i>Masticophis bilineatus</i> Jan, 1863	LC	M (11)	NL	1, 2, 3, 4, 6	2	USNM 15880 (1889)
<i>Masticophis flagellum</i> Shaw, 1802	LC	L (8)	A	1, 2, 3, 4, 6	2	USNM 56759 (1902)
<i>Masticophis mentovarius</i> (Duméril, Bibron & Duméril, 1854)	LC	L (6)	A	3, 4	4	SDNHM 18183 (1947)
<i>Masticophis slevini</i> Lowe & Norris, 1955	LC	H (17)	NL	6	0	SDNHM 3826 (1930)
<i>Mastigodryas cliftoni</i> (Hardy, 1964)	NE	H (14)	NL	4	1	UAZ 42231 (1975)
<i>Oxybelis aeneus</i> (Wagler, 1824)	NE	L (5)	NL	1, 3, 4	3	SDNHM 18189 (1947)
<i>Phyllorhynchus browni</i> Stejneger, 1890	LC	M (13)	Pr	1, 4	2	MVZ 50740 (1950)
<i>Phyllorhynchus decurtatus</i> (Cope, 1868)	LC	M (11)	NL	1	2	MVZ 10170 (1926)
<i>Pituophis catenifer</i> (Blainville, 1835)	LC	L (9)	NL	1, 2, 3, 4, 6	2	MVZ 5886 (1915)
<i>Pituophis deppoi</i> (Duméril, 1853)	LC	H (14)	A	3	1	T.R. Van Devender (son-trv-5147) (1997)
<i>Pseudocimexia frontalis</i> (Cope, 1864)	LC	M (13)	NL	4	1	UAZ 21338 (1967)
<i>Rhinocheilus lecontei</i> Baird & Girard, 1853	LC	L (8)	NL	1, 2, 3, 4	2	UMMZ 75636 (1933)
<i>Salvadora bairdii</i> Jan & Sordelli, 1860	LC	H (15)	Pr	3	1	AMNH 102194 (1968)
<i>Salvadora deserticola</i> Schmidt, 1940	NE	H (14)	NL	1, 2, 3	2	MVZ 21029 (1936)
<i>Salvadora grahamiae</i> Baird & Girard, 1853	LC	M (10)	NL	2, 3	2	UAZ 26182 (1952)
<i>Salvadora hexalepis</i> (Cope, 1867)	LC	M (10)	NL	1	2	UAZ 26300 (1905)
<i>Senticolis triaspis</i> (Cope, 1866)	LC	L (6)	NL	1, 3, 4	3	CAS HERP 63101 (1928)
<i>Sonora aemula</i> (Cope, 1879)	NT	H (16)	Pr	3, 4	1	MPM H 6448 (1900)
<i>Sonora semiannulata</i> Baird & Girard, 1853	LC	L (5)	NL	1, 2	2	UAZ 26340 (1953)
<i>Sympholis lippiens</i> Cope, 1862	NE	H (14)	NL	4	1	MVZ 76333 (1963)
<i>Tantilla hobartsmithi</i> Taylor, 1936	LC	M (11)	NL	1, 2, 3	2	LACM 20473 (1950)
<i>Tantilla wilcoxi</i> Stejneger, 1902	LC	M (10)	NL	3	2	UAZ 28201 (1964)
<i>Tantilla yaquia</i> Smith, 1942	LC	M (10)	NL	1, 3, 4	2	SDNHM 18190 (1947)
<i>Trimorphodon lambda</i> Cope, 1886	NE	M (13)	NL	1, 3, 4, 6	2	USNM 56321 91902)
<i>Trimorphodon tau</i> Cope, 1870	LC	M (13)	NL	3, 4	1	UAZ 27070 (1905)
Dipsadidae						
<i>Coniophanes lateritis</i> Cope, 1862	DD	M (13)	NL	4	1	Ambia Molina 1969 (1969)
<i>Diadophis punctatus</i> (Linnaeus, 1766)	LC	L (4)	NL	1, 2, 3	2	UAZ 24162 (1905)
<i>Geophis dugesii</i> Bocourt, 1883	LC	M (13)	NL	3	1	Enderson and Bezy 2007 (2007)
<i>Heterodon kenerlyi</i> Kennicott, 1860	NE	M (11)	Pr	2	2	USNM 1253 (1855)
<i>Hypsiglena chlorophaea</i> Cope, 1860	NE	L (8)	NL	1, 2, 3, 4, 6	2	Allen 1933 (1932)
<i>Imantodes gemmistratus</i> (Cope, 1861)	NE	L (6)	Pr	4	4	UAZ 50923 (1905)
<i>Leptodeira punctata</i> (Peters, 1866)	LC	H (17)	NL	4	1	CAS HERP 93855 (1962)
<i>Leptodeira splendida</i> Günther, 1895	LC	H (14)	NL	3, 4	1	MVZ 50835 (1950)
<i>Tropidodipsas repleta</i> Smith, Lemos-Espinal, Hartman & Chiszar, 2005	DD	H (17)	NL	3, 4	1	UCM 65700 (2003)

	IUCN	EVS	SEMARNAT	Ecoregions	GD	Source of first record
Elapidae						
<i>Hydrophis platurus</i> (Linnaeus, 1766)	LC	NE	NL	5	6	UAZ 39726 (1962)
<i>Micruroides euryxanthus</i> (Kennicott, 1860)	LC	H (15)	A	1, 3, 4, 6	2	UMMZ 78434 (1935)
<i>Micrurus distans</i> (Kennicott, 1860)	LC	H (14)	Pr	3, 4	1	MVZ 28933 (1939)
Leptotyphlopidae						
<i>Rena humilis</i> Baird & Girard, 1853	LC	L (8)	NL	1, 3, 4	2	USNM 141978 (1957)
Natricidae						
<i>Storeria storerioides</i> (Cope, 1865)	LC	M (11)	NL	3	1	UAZ 28125 (1964)
<i>Thamnophis cyrtopsis</i> (Kennicott, 1860)	LC	L (7)	A	1, 2, 3, 4	3	USNM 21056 (1893)
<i>Thamnophis eques</i> (Reuss, 1834)	LC	L (8)	A	1, 2, 3, 4	2	MCZ R-5891 (1700)
<i>Thamnophis marcianus</i> (Baird & Girard, 1853)	LC	M (10)	A	1, 2, 3	3	USNM 21822 (1894)
<i>Thamnophis melanogaster</i> (Peters, 1864)	EN	H (15)	A	3	1	BYU 13505 (1956)
<i>Thamnophis unilabialis</i> Tanner, 1985	NE	NE	NL	3	1	USNM 21055 (1893)
<i>Thamnophis validus</i> (Kennicott, 1860)	NE	M (12)	NL	4	1	KUH 47567 (1959)
Typhlopidae						
<i>Indotyphlops braminus</i> (Daudin, 1803)	N/A	N/A	N/A	N/A	IN	MZFC 6147 (1991)
Viperidae						
<i>Agkistrodon bilineatus</i> (Günther, 1863)	NT	M (11)	Pr	4	4	SDNHM 40270 (1949)
<i>Crotalus atrox</i> Baird & Girard, 1853	LC	L (9)	Pr	1, 2, 3, 6	2	USNM 21045 (1893)
<i>Crotalus basiliscus</i> (Cope, 1864)	LC	H (16)	Pr	1, 4	1	SDNHM 18181 (1947)
<i>Crotalus cerastes</i> Hallowell, 1854	LC	H (16)	Pr	1	2	CAS HERP 81515 (1947)
<i>Crotalus estebanensis</i> (Klauber, 1949)	LC	H (19)	NL	6	0	USNM 64586 (1911)
<i>Crotalus lepidus</i> (Kennicott, 1861)	LC	M (12)	Pr	3	2	SDNHM 42906 (1952)
<i>Crotalus molossus</i> Baird & Girard, 1853	LC	L (8)	Pr	1, 2, 3, 4, 6	2	SDNHM 3445 (1932)
<i>Crotalus pricei</i> Van Denburgh, 1895	LC	H (14)	Pr	3	2	UMMZ 78456 (1935)
<i>Crotalus pyrrhus</i> (Cope, 1866)	NE	NE	NL	1	2	UAZ 27600 (1964)
<i>Crotalus scutulatus</i> (Kennicott, 1861)	LC	L (11)	Pr	1, 2	2	UAZ 27355 (1930)
<i>Crotalus tigris</i> Kennicott, 1859	LC	H (16)	Pr	1, 3, 4, 6	2	SDNHM 3237 (1930)
<i>Crotalus viridis</i> (Rafinesque, 1818)	LC	M (12)	Pr	2	2	USNM 61955 (1887)
<i>Crotalus willardi</i> Meek, 1905	LC	M (13)	Pr	3	2	UMMZ 78449 (1935)
Order Testudines						
Chelonidae						
<i>Caretta caretta</i> (Linnaeus, 1758)	VU	NE	P	5	5	UAZ 36495 (1954)
<i>Chelonia mydas</i> (Linnaeus, 1758)	EN	NE	P	5	5	USNM 21818 (1894)
<i>Eretmochelys imbricata</i> (Linnaeus, 1766)	NE	NE	P	5	5	Grismer, 2002 (2002)
<i>Lepidochelys olivacea</i> (Eschscholtz, 1829)	VU	NE	P	5	5	SDNHM 49849 (1961)
Dermochelyidae						
<i>Dermochelys coriacea</i> (Vandelli, 1761)	VU	NE	P	5	5	UAZ 40133 (1974)
Emydidae						
<i>Terrapene nelsoni</i> Stejneger, 1925	DD	H (18)	Pr	3, 4	1	SDNHM 42411 (1930)
<i>Terrapene ornata</i> (Agassiz, 1857)	NT	H (15)	Pr	2, 3	2	USNM 20993 (1893)
<i>Trachemys nebulosa</i> (Van Denburgh, 1895)	NE	H (18)	NL	4	1	UMNH 3823 (1961)
<i>Trachemys jaquía</i> (Legler & Webb, 1970)	VU	H (19)	NL	1, 3, 4	0	UMNH 12449 (1963)
Geoemydidae						
<i>Rhinoclemmys pulcherrima</i> (Gray, 1855)	NE	L (8)	NL	4	4	MVZ 50913 (1950)
Kinosternidae						
<i>Kinosternon alamosae</i> Berry & Legler, 1980	DD	H (14)	Pr	1, 4	1	MVZ 50907 (1950)
<i>Kinosternon arizonense</i> Gilmore, 1922	LC	H (15)	NL	1	2	UMMZ 72234 (1950)
<i>Kinosternon integrum</i> LeConte, 1854	LC	M (11)	Pr	1, 3, 4	1	UMMZ 79514 (1935)
<i>Kinosternon sonoriense</i> Le Conte, 1854	NT	H (14)	P	1, 2, 3	2	USNM 20984 (1893)
Family Testudinidae						
<i>Gopherus evgoodei</i> Edwards, Karl, Vaughn, Rosen, Meléndez-Torres, & Murphy, 2016	NE	NE	NL	3, 4	1	ROM 53301 (1942)
<i>Gopherus morafkai</i> Murphy, Berry, Edwards, Leviton, Lathrop, & Riedle, 2011	NE	H (15)	NL	1, 3, 6	2	USNM 21159 (1894)
Trionychidae						
<i>Apalone spiniferus</i> (Le Sueur, 1827)	N/A	N/A	N/A	N/A	IN	UAZ 56727-PSV (2007)

Table 3. Summary of native species present in Sonora by family, order or suborder, and class. Status summary indicates the number of species found in each IUCN conservation status in the order DD, LC, VU, NT, EN, CE (see Table 2 for abbreviations; in some cases species have not been assigned a status by the IUCN and therefore these may not add up to the total number of species in a taxon) and conservation status in Mexico according to SEMARNAT (2010) in the order NL, Pr, A, and P (see Table 1 for abbreviations). Mean EVS is the mean Environmental Vulnerability Score, scores ≥ 14 are considered high vulnerability (Wilson et al. 2013a, b).

Scientific Name	Genera	Species	IUCN	EVS	SEMARNAT
Class Amphibia					
Order Anura	15	33	2,24,3,1,0,0	9.3	25,7,1,0
Bufonidae	3	12	0,9,0,1,0,0	10.6	10,2,0,0
Craugastoridae	1	3	1,1,1,0,0,0	12.7	2,1,0,0
Eleutherodactylidae	1	1	1,0,0,0,0,0	15	0,1,0,0
Hylidae	4	6	0,6,0,0,0,0	8.5	6,0,0,0
Leptodactylidae	1	1	0,1,0,0,0,0	6	1,0,0,0
Microhylidae	2	2	0,1,0,0,0,0	6	2,0,0,0
Ranidae	1	6	0,4,2,0,0,0	8.2	2,3,1,0
Scaphiopodidae	2	2	0,2,0,0,0,0	4.5	2,0,0,0
Order Caudata	2	3	0,2,0,0,0,0	12	2,1,0,0
Ambystomatidae	1	2	0,2,0,0,0,0	12	1,1,0,0
Plethodontidae	1	1	0,0,0,0,0,0		1,0,0,0
Subtotal	17	36	2,26,3,1,0,0	9.4	27,8,1,0
Class Reptilia					
Order Crocodylia	1	1	0,0,1,0,0,0	14	0,1,0,0
Crocodylidae	1	1	0,0,1,0,0,0	14	0,1,0,0
Order Squamata	60	140	6,90,3,5,1,0	12.2	91,29,20,0
Suborder Lacertilia	21	66	4,40,3,3,0,0	13.5	46,10,10,0
Anguidae	1	1	0,1,0,0,0,0	10	0,1,0,0
Crotaphytidae	2	4	0,4,0,0,0,0	13.5	2,1,1,0
Dactyloidae	1	1	0,1,0,0,0,0	13	1,0,0,0
Eublepharidae	1	2	0,2,0,0,0,0	14	1,1,0,0
Helodermatidae	1	2	0,0,0,1,0,0	15	1,0,1,0
Iguanidae	3	6	0,2,1,0,0,0	15.3	4,1,1,0
Phrynosomatidae	8	29	2,19,1,2,0,0	13.2	22,0,7,0
Phyllodactylidae	1	4	0,2,0,0,0,0	11	3,1,0,0
Scincidae	1	3	1,2,0,0,0,0	12.7	2,1,0,0
Teiidae	1	12	1,6,1,0,0,0	14	8,4,0,0
Xantusidae	1	2	0,1,0,0,0,0	16	2,0,0,0
Suborder Serpentes	39	74	2,51,0,2,1,0	11.1	45,19,10,0
Boidae	2	2	0,1,0,0,0,0	10	1,0,1,0
Colubridae	21	39	0,27,0,1,0,0	10.5	30,5,4,0
Dipsadidae	8	9	2,4,0,0,0,0	11.4	7,2,0,0
Elapidae	3	3	0,3,0,0,0,0	14.5	1,1,1,0
Leptotyphlopidae	1	1	0,1,0,0,0,0	8	1,0,0,0
Natricidae	2	7	0,4,0,0,1,0	10.5	3,0,4,0
Viperidae	2	13	0,11,0,1,0,0	13.1	2,11,0,0
Order Testudines	10	16	2,2,4,2,1,0	14.7	6,4,0,6
Cheloniidae	4	4	0,0,2,0,1,0		0,0,0,4
Dermochelyidae	1	1	0,0,1,0,0,0		0,0,0,1
Emydidae	2	4	1,0,1,1,0,0	17.5	2,2,0,0
Geoemydidae	1	1	0,0,0,0,0,0	8	1,0,0,0
Kinosternidae	1	4	1,2,0,1,0,0	13.5	1,2,0,1
Testudinidae	1	2	0,0,0,0,0,0	15	2,0,0,0
Subtotal	71	157	8,93,8,7,2,0	12.4	97,34,20,6
Total	88	193	10,119,11,8,2,0	11.9	124,42,21,6

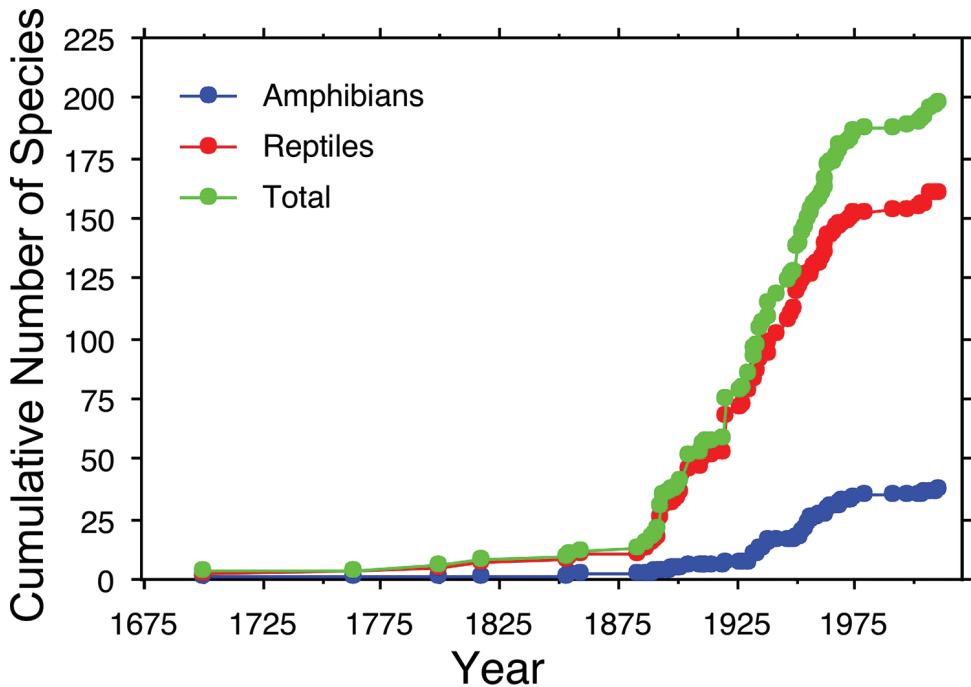


Figure 6. Species accumulation curves for the amphibians, reptiles, and total herpetofauna of Sonora, Mexico.

from Canada to Central America, from the US to Central or South America, or from Mexico to Central or South America (Table 2).

The American Crocodile (*Crocodylus acutus*) is widely distributed from the eastern US to South America. One of the seventeen species of turtles that inhabit the state is endemic to Sonora (Table 2). Five more are endemic to Mexico. Of the eleven species of turtles not endemic to Mexico that occur in Sonora, one is introduced. Four more are distributed from the US to Mexico, one more is found from Mexico to Central America, and the remaining five species have a circumtropical or circumglobal distribution (Table 2). Fourteen of the 69 species of lizards that occur in the state are endemic to Sonora, nine of them to islands of the Gulf of California. Thirteen more are endemic to Mexico (Table 2). Of the 42 lizard species not endemic to Mexico that inhabit Sonora, three are introduced, 38 more are found in the US and Mexico, and the remaining species have a wide distribution that includes Mexico and South America (*Phyllodactylus tuberculosus*) (Table 2). Two of the 75 species of snakes that inhabit the state are endemic to Sonoran islands of the Gulf of California (Table 2). Another 21 snake species that are found in Sonora are endemic to Mexico. Of the 52 snake species not endemic to Mexico that occur in Sonora, one is introduced, 41 more are distributed from the US to Mexico, six more range from the US or Canada to Central or even South America, and three more are found from Mexico to Central or South America (Table 2).

Ecoregions

The most diverse Sonora ecoregions in terms of the herpetofauna are the Eastern mountains (54% of the total number of amphibian and reptile species for the state) represented by the Sierra Madre Occidental and associated mountains, and the Western Mainland Desert (49%) represented mainly by the Sonoran Desert (Fig. 4). The Island (16%) and Marine (4%) are the least occupied ecoregions (Table 5). In general, the highest richness of amphibian species is observed in the Subtropical Lowlands and Foothills of the Sierra Madre Occidental with 61% of the total number of species, followed by the Eastern Mountains (58%), the Western Mainland Deserts (50%), and the High Northeastern Valleys (39%). Amphibians are almost absent in the Island ecoregion with only two species recorded (6%) and due to their limitations to inhabit saline environments they are absent in the Marine ecoregion (Table 5). The Subtropical Lowlands and Foothills of the Sierra Madre Occidental had 67% of the anuran species in Sonora, whereas caudate amphibians are absent in this ecoregion showing their highest percentage of presence in the Eastern Mountains with two (67%) of the three species occurring in this ecoregion. In reptiles, the highest species richness is found in the Eastern Mountains (53%) ecoregion. This is the ecoregion with the highest number of snake (61%) and turtle (44%) species, although the same number of turtle species is found in the Subtropical Lowlands and Foothills of the Sierra Madre Occidental. Snakes are also diverse in the Western Mainland Deserts and the Subtropical Lowlands and Foothills of the Sierra Madre Occidental; each of these ecoregions hosts 38 snake species (51% of the total number of snake species recorded in Sonora). On the other hand, due to their conspicuousness and adaptations for arid environments, lizards have their highest diversity in the Western Mainland Deserts (48%) followed by the Eastern Mountains (47%), and they are the most diverse taxonomic group in the Island ecoregion, which is represented by dry environments, with 15 species (23%). Snakes are also diverse in the Island ecoregion with 13 species (18%). This is explained in part by the high vagility, adaptations to dry environments, and speciation rates of these two squamate suborders. Testudines is the taxonomic group with the highest percentage of species (5 = 31% of the total number of turtles in Sonora) in the Marine ecoregion, followed by snakes and crocodilians, both groups with one species representing 1 and 100% of the total number of species in their groups respectively. Five of the species that occur in the Marine ecoregion have a circumglobal or circumtropical distribution (five turtles). The other two species occurring in the Marine ecoregion are a crocodile that was thought until recently to be extirpated from Sonora but may be staging a comeback on the southern coast (Rorabaugh 2017), and a sea snake distributed across the Pacific and Indo-Pacific Oceans. The general reptile pattern of diversity is driven by lizards and snakes, except in the Marine ecoregions which is dominated by sea turtles of the families Cheloniidae and Dermochelyidae (Table 5).

Table 4. List of amphibians and reptiles that could potentially occur in Sonora.

Class Amphibia	
Order Anura	
Craugastoridae	
<i>Craugastor vocalis</i> (Taylor, 1940)	Likely to occur in tropical deciduous forest and montane woodlands in the Río Fuerte drainage of extreme southeastern Sonora.
Ranidae	
<i>Rana blairi</i> (Mecham, Littlejohn, Oldham, Brown, & Brown, 1973)	Likely to occur in Chihuahuan Desert or semi-desert grassland of northeastern Sonora, along the US-Mexico border east of Naco.
Scaphiopodidae	
<i>Spea bombifrons</i> (Cope, 1863)	Likely to occur in Chihuahuan desertscrub east and plains grassland of northeastern Sonora.
Class Reptilia	
Order Squamata	
Suborder Amphisbaenia	
<i>Bipes biporus</i> (Cope, 1894)	This species has been observed in the San Carlos Bay, municipality of Guaymas (Ballinger pers. comm., May 2009), but no museum record or voucher exist to support its presence in Sonora.
Suborder Lacertilia	
Anguidae	
<i>Barisia levicollis</i> (Smith, 1942)	Likely to occur in woodlands of the Sierra Madre Occidental of eastern and northeastern Sonora
Phrynosomatidae	
<i>Sceloporus bimaculosus</i> Phelan & Brattstrom, 1955	Expected in Chihuahuan desertscrub and semi-desert grassland valleys as well as the lower slopes of the mountains along the US – Mexico border from the Río San Pedro valley east to the Sierra San Luis, and potentially in Plains grassland in the southern Animas Valley (northeastern Sonora).
Scincidae	
<i>Plestiodon multilineatus</i> (Tanner, 1957)	Likely to occur in woodland of the Sierra Madre Occidental of eastern and northeastern Sonora
Suborder Serpentes	
Boidae	
<i>Lichanura orcutti</i> Stejneger, 1889	Has been found within a few km of the Sonora border in the Tinajas Altas Mountains of Yuma County, Arizona
Colubridae	
<i>Lampropeltis gentilis</i> (Baird & Girard, 1853)	Occurs in southeastern Cochise County, Arizona
<i>Tantilla nigriceps</i> Kennicott, 1860	Likely occurs in northeastern Sonora in Chihuahuan desertscrub or semi-desert grassland from Agua Prieta east to the Sierra San Luis and possibly in Plains grassland in the southern Animas Valley.
Dipsadidae	
<i>Hypsigena jani</i> Duges, 1865	Likely to occur in tropical deciduous forest and scrubland of southeastern Sonora.
<i>Hypsigena torquata</i> (Günther, 1860)	Likely to occur in tropical deciduous forest and scrubland of southeastern Sonora. Mulcahy et al. (2014) suggested the snakes in this area might be an undescribed species of <i>Hypsigena</i> .
<i>Rhadinaea laureata</i> (Günther, 1868)	Likely to occur in woodlands of the Sierra Madre Occidental of eastern and northeastern Sonora
Leptotyphlopidae	
<i>Rena dissecta</i> (Cope, 1896)	Expected in Chihuahuan desertscrub, semi-desert grasslands, and into the lower slopes of adjacent mountains along the United States - Mexico border from the Río San Pedro Valley east to the Sierra San Luis, and also in Plains grassland in the southern Animas Valley.
Natricidae	
<i>Thamnophis elegans</i> (Baird & Girard, 1853)	This species might occur in the Sierras Huachinera and Bacadehuachi and possibly elsewhere in the eastern mountains of Sonora near the Chihuahua border.
Viperidae	
<i>Sistrurus tergeminus</i> (Say, 1823)	Could potentially be found in grasslands along the US – Mexico border from the Río San Pedro Valley east to the Sierra San Luis.
Order Testudines	
Emydidae	
<i>Trachemys scripta</i> (Thunberg, 1792)	This aquatic turtle occurs sparingly as an introduced species in the Colorado River near Yuma, Arizona and in the San Pedro River Valley of Arizona. It could be present along wetted reaches of the Río Colorado in Sonora or in agricultural canals and ditches in that region, and in the Río San Pedro of Sonora near the border with Arizona.

Table 5. Summary of the number of native species (% of total number of species of taxonomic group in Sonora in parentheses) in different taxonomic groups found in the ecoregions of Sonora, Mexico (see text for description of the ecoregion types).

	Western mainland deserts	High northeastern valleys	Eastern mountains	Subtropical lowlands and foothills	Marine	Island
Amphibia	18 (50)	14 (39)	21 (58)	22 (61)	0 (0)	2 (6)
Anura	17 (52)	13 (39)	19 (58)	22 (67)	0 (0)	2 (6)
Caudata	1 (33)	1 (33)	2 (67)	0 (0)	0 (0)	0 (0)
Reptilia	76 (48)	40 (31)	83 (53)	61 (39)	7 (4)	29 (18)
Crocodylia	0 (0)	0 (0)	0 (0)	0 (0)	1 (100)	0 (0)
Squamata	70 (50)	38 (27)	76 (54)	54 (39)	1 (0.07)	28 (20)
Lacertilia	32 (48)	17 (26)	31 (47)	16 (24)	0 (0)	15 (23)
Serpentes	38 (51)	21 (28)	45 (61)	38 (51)	1 (1)	13 (18)
Testudines	6 (40)	2 (13)	7 (44)	7 (44)	5 (31)	1 (6)
Total	94 (49)	54 (28)	104 (54)	83 (43)	7 (4)	30 (16)

Comparisons with neighboring states

Overall, Sonora shares the most species with Chihuahua, Sinaloa, and Arizona (Table 6). For amphibians, Sonora shares the most species with Chihuahua and Sinaloa. For reptiles, Sonora shares about half its species with Chihuahua, Sinaloa, and Arizona (Table 6). Previous comparisons of shared herpetofaunal species among neighboring states in the US-Mexico border region found high levels of similarity between Sonora and Chihuahua (Enderson et al. 2009, Smith and Lemos-Espinal 2015, Lemos-Espinal et al. 2017). However, an analysis based on “biogeographic affinity” resulted in Sonora being closest or most similar to Sinaloa (Enderson et al. 2009, Lavín-Murcio and Lazcano 2010). There is some variation, though, in these affinities depending on which specific herpetofaunal taxa are being examined (Enderson et al. 2009). Such a pattern probably reflects the fact that Sonora, Chihuahua, Arizona, and Sinaloa all have extensive tracts of arid habitats. Shared habitats and vegetation types likely lead to similarities in species among Sonora and neighboring states (see also Smith and Lemos-Espinal 2015, Lemos-Espinal and Smith 2016, Lemos-Espinal et al. 2017). The similarity in herpetofauna among three Mexican states and Arizona highlights the necessity for interstate and international approaches to conserving and managing habitats and species (e.g., Grigione et al. 2009, Wiederholt et al. 2013).

Conservation status

A total of 21 (= 10.9%) species of amphibians and reptiles is IUCN listed (i.e., Vulnerable, Near Threatened, Endangered, or Critically Endangered), but 69 species (= 35.0%) are placed in a protected category by SEMARNAT and 63 species (= 32.6%) are categorized as high risk by the EVS (Tables 3, 5). For amphibians, 11.1% are IUCN

Table 6. Summary of the numbers of species shared between Sonora and neighboring Mexican states (not including introduced species). The percent of species from Sonora shared by a neighboring state are given in parentheses. Key: – indicates neighboring state has no species in the taxonomic group, thus no value for shared species is provided.

	Sonora	Arizona	Baja California	Sinaloa	Chihuahua	New Mexico
Class Amphibia	36	16 (44)	6 (17)	25 (69)	30 (83)	13 (36)
Order Caudata	3	1 (33)	0 (0)	1 (33)	3 (100)	1 (33)
Ambystomatidae	2	1 (50)	–	1 (50)	2 (100)	1 (50)
Plethodontidae	1	0 (0)	0 (0)	–	1 (100)	0 (0)
Order Anura	33	15 (45)	6 (18)	24 (73)	27 (82)	12 (36)
Bufonidae	12	6 (50)	4 (33)	8 (67)	9 (75)	5 (42)
Craugastoridae	3	1 (33)	–	2 (67)	2 (67)	1 (33)
Eleutherodactylidae	1	–	–	1 (100)	1 (100)	–
Hylidae	6	3 (50)	0 (0)	5 (83)	5 (83)	2 (33)
Leptodactylidae	1	–	–	1 (100)	–	–
Microhylidae	2	0 (0)	–	2 (100)	2 (100)	0 (0)
Ranidae	6	3 (50)	1 (17)	4 (67)	6 (100)	2 (33)
Scaphiopodidae	2	2 (100)	1 (50)	1 (50)	2 (100)	2 (100)
Class Reptilia	158	88 (56)	36 (23)	85 (54)	94 (59)	61 (39)
Order Crocodylia	1	–	–	1 (100)	–	–
Order Testudines	16	4 (25)	5 (31)	12 (75)	6 (38)	2 (12)
Cheloniidae	4	–	4 (100)	4 (100)	–	–
Dermochelyidae	1	–	1 (100)	1 (100)	–	–
Emydidae	4	1 (25)	0 (0)	2 (50)	2 (50)	1 (25)
Geoemydidae	1	–	–	1 (100)	1 (100)	–
Kinosternidae	4	2 (50)	–	2 (50)	2 (50)	1 (25)
Testudinidae	2	1 (50)	–	2 (100)	1 (50)	–
Order Squamata	141	84 (60)	31 (22)	72 (51)	88 (62)	59 (42)
Suborder Lacertilia	66	37 (56)	12 (18)	25 (38)	32 (48)	29 (44)
Anguidae	1	1 (100)	0 (0)	1 (100)	1 (100)	1 (100)
Crotaphytidae	4	3 (75)	1 (25)	–	2 (50)	2 (50)
Dactyloidae	1	–	–	1 (100)	1 (100)	–
Eublepharidae	2	1 (50)	1 (50)	1 (50)	0 (0)	1 (50)
Helodermatidae	2	1 (50)	–	2 (100)	1 (50)	1 (50)
Iguanidae	6	2 (33)	2 (33)	2 (33)	1 (17)	–
Phrynosomatidae	29	20 (69)	6 (21)	12 (41)	18 (62)	17 (59)
Phyllodactylidae	4	–	1 (25)	2 (50)	1 (25)	–
Scincidae	3	2 (67)	0 (0)	2 (67)	3 (100)	2 (67)
Teiidae	12	6 (50)	1 (8)	2 (17)	4 (33)	5 (42)
Xantusidae	2	1 (50)	0 (0)	–	–	–
Suborder Serpentes	75	47 (63)	19 (25)	47 (63)	56 (75)	30 (40)
Boidae	2	1 (50)	1 (50)	1 (50)	1 (50)	–
Colubridae	40	28 (70)	10 (25)	26 (65)	29 (72)	17 (42)
Dipsadidae	9	3 (33)	2 (22)	7 (78)	7 (78)	3 (33)
Elapidae	3	1 (33)	1 (33)	3 (100)	2 (66)	1 (33)
Leptotyphlopidae	1	1 (100)	1 (100)	1 (100)	1 (100)	0 (0)
Natricidae	7	3 (43)	1 (14)	3 (43)	7 (100)	3 (43)
Viperidae	13	10 (77)	3 (23)	6 (46)	9 (69)	6 (46)
Total	194	104 (53)	42 (22)	110 (57)	124 (64)	74 (38)

listed, 25.0% are protected by SEMARNAT, and 13.8% are at high risk according to the EVS (Tables 3, 5). For reptiles, 10.8% are listed by the IUCN, 38.2% are protected by SEMARNAT, and 36.3% are at high risk according to the EVS (Tables 3, 5). These results suggest that the herpetofauna, especially the reptiles, of Sonora is considered to be of relatively low conservation concern at a global scale, but there is much greater conservation concern at a national level. Indeed, more local assessments (SEMARNAT and EVS) are based on information specific to Mexico and thus are more likely to reflect the conservation needs of the Sonoran herpetofauna (see Lemos-Espinal et al. 2018a,b for a similar assessment for other Mexican states). There are several taxa that, based on their IUCN listing, SEMARNAT category or their EVS, are of conservation concern. Families that include species of particular conservation concern include Bufonidae, Craugastoridae, Eleutherodactylidae, Ranidae, Ambystomidae, Crocodylidae, Helodermatidae, Iguanidae, Phrynosomatidae, Phyllodactylidae, Teiidae, Xantusidae, Colubridae, Dipsadidae, Elapidae, Natricidae, Viperidae, Cheloniidae, Dermochelyidae, Emydidae, Kinosternidae, and Testudinidae (Tables 3, 5). Because the IUCN, SEMARNAT, and EVS categories are based on global or country-level assessments, there are likely amphibians and reptiles whose conservation status in Sonora is not accurately assessed by these measures. Additional assessments at the state level in Sonora, and other Mexican states, are needed to establish conservation or management needs for particular states, or even regions. As an example, frogs in the family Ranidae in Sonora, some of which are considered of conservation concern, are at risk from habitat loss, disease (chytridiomycosis), and predation by introduced species (Rorabaugh and Lemos-Espinal 2016).

To help determine which ecoregions within Sonora support species of particular conservation concern, we summarized the conservation status of reptile and amphibian taxa in each ecoregion found in Sonora (Tables 2, 3). In regard to IUCN categories, none of the amphibians in the Western Mainland Deserts, Subtropical Lowlands and Foothills of the Sierra Madre Occidental, and Island ecoregions are listed; however, one species (2.8%) in the High Northeastern Valleys, and three (8.3%) in the Eastern Mountains ecoregions are included. For SEMARNAT categories, 16.7% of amphibians in the Western Mainland Deserts ecoregion, 14.3% in the High Northeastern Valleys ecoregion, 28.6% in the Eastern Mountains ecoregion, and 18.2% in the Subtropical Lowlands and Foothills of the Sierra Madre Occidental ecoregion are listed. For EVS, 44.4% of the amphibians in the Western Mainland Deserts ecoregion were in the low and medium categories, and 5.6%, represented by only one species, was in the high category; the remaining 5.6% are represented by a species not evaluated. More than half (57.1%) of the amphibians in the High Northeastern Valleys ecoregion are in the low category, and 42.9% are in the medium category; no species in this ecoregion is in the high category. In the Eastern Mountains ecoregion, 38.1% of amphibian species are in the low and medium categories, 19.0% in the high, and the remaining 4.8% are represented by a species not evaluated. For the Subtropical Lowlands and Foothills of the Sierra Madre Occidental ecoregion, 50.0% are in the low category, 36.4% are in the medium category, and 9.1% are in the high category; the remaining 4.5% are represented by a species not evaluated. For the Island ecoregion, the two species occurring in this ecoregion are in the low category.

For the IUCN listings, all ecoregions, except the Marine ecoregion, have relatively few species of reptiles in the protected categories (Western Mainland Deserts [5 = 6.6%], High Northeastern Valleys [3 = 7.5%], Eastern Mountains [6 = 7.2%], Subtropical Lowlands and Foothills of the Sierra Madre Occidental [4 = 6.6%], and Island [3 = 10.5%]). Nearly all of the reptiles in the Marine ecoregion (6 = 85.7%) are in the protected categories. However, for the IUCN listing a total of 38 reptile species have not been evaluated, most of them are species recently described or not recognized by the IUCN as populations that deserve species status, but all of them are species with a narrow distribution, which increases their vulnerability. On the other hand, 36.8% of reptiles in the Western Mainland Deserts region, 42.5% from the High Northeastern Valleys ecoregion, 35.4% from the Eastern Mountains ecoregion, 37.1% from the Subtropical Lowlands and Foothills of the Sierra Madre Occidental ecoregion, 85.7% of the Marine ecoregion, and 41.4% from the Island ecoregion are in the protected SEMARNAT categories. For the Western Mainland Deserts ecoregion, 26.3% of the reptiles are in the low EVS category, 36.8% in the medium, and 32.9% in the high; the remaining 3.9% are represented by three species not evaluated. In the High Northeastern Valleys ecoregion, 27.5% of the reptiles are in the low, 47.5% in the medium, and 22.5% in the high category; the remaining 2.5% are represented by a species not evaluated. Of the reptiles in the Eastern Mountains ecoregion, 19.5% are in the low, 39.0% in the medium, and 35.4% in the high category; the remaining 6.1% are represented by five species not evaluated. For the Subtropical Lowlands and Foothills of the Sierra Madre Occidental, 27.4% are in the low EVS category, 32.3% in the medium, and 33.9% in the high; the remaining 6.5% are represented by four species not evaluated. Of the seven reptile species that occur in the Marine ecoregion, only one (14.3%) is in the high category; the other six species (85.7%) are species that have not been evaluated. In the Island ecoregion, 17.2% are in the low EVS category, 24.1% in the medium, and 48.3% in the high; the remaining 10.3% are represented by three species not evaluated. Thus, the reptiles in the Marine ecoregion are clearly the most threatened of the Sonoran herpetofauna.

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Appendix I

Museum collections included in the CONABIO database examined for records of Sonoran amphibians and reptiles or that house specimens of the first record of a species in Sonora.

AMNH	Collection of Herpetology, Herpetology Department, American Museum of Natural History
ANSP	Collection of Herpetology, Herpetology Department, Academy of Natural Sciences of Philadelphia
ASNHC	Herpetology Collection, Angelo State Natural History Collections, Angelo State University
ASU	Arizona State University
NHMUK	Collection of Herpetology, Zoology Department, The Natural History Museum, London, UK
BYU	Monte L. Bean Life Science Museum, Brigham Young University, Provo, Utah
CAS	Collection of Herpetology, Herpetology Department, California Academy of Sciences
CMNH	Collection of Herpetology, Amphibian and Reptile Section, Carnegie Museum of Natural History, Pittsburgh
CNAR	Colección Nacional de Anfibios y Reptiles, Instituto de Biología UNAM
CUMV	Amphibian and Reptile Collection, Cornell University Museum of Vertebrates
ENCB	Colección Herpetológica, Departamento de Zoología, Escuela Nacional de Ciencias Biológicas
FMNH	Division of Amphibians and Reptiles, Field Museum of Natural History
FSM-UF	Collection of Herpetology, Florida State Museum, University of Florida
LACM	Collection of Herpetology, Herpetology Section, Natural History Museum of Los Angeles County
LEUBIPRO	Laboratorio de Biología UBIPRO
LSUMZ	Collection of Herpetology, Museum of Zoology, Biological Science Division, Louisiana State University
MCZ	Collection of Herpetology, Museum of Comparative Zoology, Harvard University Cambridge
MNHUK	Museum of Natural History, Division of Herpetology, University of Kansas
MPM	Herpetology, Milwaukee Public Museum
MVZ	Collection of Herpetology, Museum of Vertebrate Zoology, Division of Biological Sciences, University of California Berkeley

MZFC-UNAM	Colección Herpetológica, Museo de Zoología “Alfonso L. Herrera”, Facultad de Ciencias UNAM
PBDB	Paleobiology Database, Paleobiology Database Chordates
ROM	Department of Herpetology, Royal Ontario Museum, Toronto, Ontario, Canada
SDNHM	Collection of Herpetology, Herpetology Department, San Diego Natural History Museum
TCWC	Collection of Herpetology, Texas Cooperative Wildlife Collection, Texas A&M University
TNHC	Collection of Herpetology, Texas Natural History Collection, University of Texas Austin
TU	Collection of Herpetology, Biology Department, Tulane University, New Orleans
UABC	Colección Herpetológica, Universidad Autónoma de Baja California
UAZ	Amphibians and Reptiles Collections, University of Arizona
UCM	Collection of Herpetology, University of Colorado Museum
UIMNH	Collection of Herpetology, University of Illinois Museum of Natural History
UIUC	Collection of Herpetology, Museum of Natural History, University of Illinois at Urbana-Champaign
UMMZ	Collection of Herpetology, Museum of Zoology, University of Michigan Ann Arbor
UMNH	Reptiles and Amphibians Collection, Natural History Museum of Utah
USNM	Collection of Herpetology, Department of Vertebrate Zoology, National Museum of Natural History, Smithsonian Institution
UTAMM	Merriam Museum, University of Texas Arlington
UTEP	Collection of Herpetology, Laboratory of Environmental Biology, Biological Science Department, University of Texas – El Paso

Corrigendum: Revision of the ant genus *Melophorus* (Hymenoptera, Formicidae). ZooKeys 700: 1–420 (2017). <https://doi.org/10.3897/zookeys.700.11784>

Brian E. Heterick^{1,2}, Mark Castalanelli³, Steve O. Shattuck⁴

1 Curtin University of Technology, GPO Box U1987, Perth WA 6845, Australia **2** Western Australian Museum, Locked Bag 49, Welshpool WA 6986, Australia **3** EcoDiagnostics Pty Ltd, 46–48 Banksia Rd, Welshpool WA 6106, Australia **4** C/o CSIRO Entomology, P.O. Box 1700, Canberra, ACT 2601, Australia

Corresponding author: Brian E. Heterick (B.Heterick@Curtin.edu.au)

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Melophorus bruneus was described by McAreavey in 1949. The itemization of the type material for this species on page 235 under ‘Descriptions’ was as follows:

‘Types

Holotype minor worker carded with paratype major worker and queen on top card, and paratype major worker and paratype minor worker of bottom card, all on same pin, also paratype major, minor and media workers and queens on two other pins, Nyngan New South Wales [ANIC] (examined: ANIC specimens ANIC32-05344).’

This itemization is incorrect. For some unaccountable reason males on both the holotype pin and one of the two paratype pins were apparently mistaken for minor workers. There is also a small typographical error (‘of bottom card’ should read ‘on bottom card’). The correct itemization should be:

‘Types

Holotype minor worker carded with paratype major worker and queen on top card, and paratype major worker and paratype male on bottom card, all on same pin, also paratype major and minor workers, queens and males on a second pin, and paratype major and media workers on a third pin, Nyngan New South Wales [ANIC] (examined: ANIC specimens ANIC32-05344).’

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