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FORUM PAPER

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Proposed Amendments to the Constitution of the International Commission on Zoological Nomenclature

International Commission on Zoological Nomenclature[1]

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Introduction

The International Commission on Zoological Nomenclature (ICZN, or Commission) considered amendments to Articles of its Constitution (ICZN 1999a) at a special session in Singapore, convened on June 3–7, 2019. During this meeting, Commissioners also planned revisions to the Bylaws, the current International Code of Zoological Nomenclature (ICZN 1999b, 2003, 2012, 2017) and ZooBank user policies.

The Commissioners voted to begin the process required to amend the Constitution. Notably, revisions were proposed and approved in principle by majority vote to clarify and update Constitutional Articles pertaining to:

1. Commissioners' terms of service (Article 3);
2. inclusion of the ICZN web site as a required venue for information dissemination (Articles 2.1, 4.2 and 12.2);
3. outdated concepts (such as the ITZN, Article 13, or postal voting, Articles 4.6, 12.2, 16.1.4 and 16.1.5), and new responsibilities (such as Zoobank, Article 14.5);
4. duration of votes on amendments to the Code and Constitution (Article 16.1.4); and
5. separation of Procedures of the Commission from its Bylaws (Article 17).

Some Constitutional Articles were also proposed to be revised for consistency and accuracy, including:

1. Article 2.1 ("contact information" instead of "addresses");
2. Article 4.1.1 ("countries of residence" instead of "nationalities"); and
3. adding "Executive" before "Secretary" in Articles 5.2, 7.1 and 14 to bring these Articles into accord with Articles 4.3, 5.3 and 9.

Procedure for amendment

The Constitution of the ICZN (Article 12.2) requires publication of notice of a proposed amendment of the Constitution in the *Bulletin of Zoological Nomenclature* (*BZN*), and submission to at least three other journals, for comment from the zoological community for at least one year prior to the Commissioners' voting on the proposed amendment (Article 16.1.2). The one-year period for comment on the current proposal, prior to any vote, will start on 30 April 2020, with the publication of notice in the *Bulletin of Zoological Nomenclature*. A copy of the proposed amendment will also be posted on the ICZN web site (www.iczn.org).

The ICZN requests comments from the community of zoologists on various parts of this amendment, either opposing, supporting, or suggesting improvements and alternatives. The Commission will revise the amendment in light of comments received from zoologists (Constitution Article 16.1.4). Comments that have been vetted for content and language will be published in *BZN* with open access and posted on the ICZN web site (www.iczn.org).

Formal comments should be sent to Dr Gwynne Lim, Executive Secretary of the ICZN (iczn@nus.edu.sg). Zoologists may also contact ICZN Commissioners directly for informal discussions (https://www.iczn.org/about-the-iczn/commissioners/). Assuming that sufficient consensus is reached in the zoological community, the final-worded amendment will be presented to the International Union of Biological Sciences (IUBS) for provisional ratification (Constitution Article 16.1.5.1). Effective ratification will be contingent on a subsequent vote by the Commission (Constitution Article 16.1.5.1). The decision and date of effective ratification will be published in *BZN* (Constitution Article 16.1.6).

Proposed amendment

In the proposed amendment, normal font represents existing text of the Constitution that is retained. Strikethrough text is existing text that is to be deleted in the amended Articles. Underlined text is new text. Indented text in square brackets describes the changes. The amendment affects Articles 2, 3, 4, 5, 7, 9, 12, 13, 14, 16, and 17.

Article 2. Membership of the Commission.

[Article 2.1 is to be revised to specify "contact details" instead of "addresses" and to include the ICZN web site as a source of information]

2.1. Number.

The Commission shall ordinarily consist of 18 members or such larger number as the Commission may decide. The names and contact details ~~addresses~~ of the members at any given time shall be published in the *Bulletin of Zoological Nomenclature* and on the Commission web site.

[Articles 2.2 and 2.3 are unchanged.]
[Article 3 is to be revised to include the criteria for eligibility of re-election specified by Article 3.2]

Article 3. Term of service and eligibility of members of the Commission.

[Article 3.1 is to be reformulated to simplify the rules for Commissioners' terms of service and to eliminate the class system. Articles 3.1.1, 3.1.2 and 3.1.3 are to be deleted, and elements of Article 3.2 are to be simplified and merged into revised Articles 3.1.1 (length of term of service) and 3.1.2 (term of service for the President of the Commission).]

3.1. ~~Normal~~ Term of service.

3.1.1. The ~~normal~~ term of service of a member of the Commission ~~shall be reckoned as follows:~~ is eighteen years.

3.1.2. The term of service of the President of the Commission shall end at the end of the term indicated in the Bylaws even if it exceeds the eighteen years term of service above.

[Article 3.2 is to be revised to simplify the rules for re-election of existing Commissioners. Article 3.2.1 is to be deleted, having been subsumed within revised Article 3.1.1. Article 3.2.2 is to be reformulated as part of revised Article 3.2.1. Article 3.2.2.1 is to be reformulated as part of revised Article 3.2.2. Article 3.2.3 is to be deleted.]

3.2. ~~Maximum term of service and~~ Eligibility for re-election.

A member whose ~~normal~~ term of service has terminated ~~terminates~~ may be re-elected but:

3.2.1. on completion of the period specified in Article 3.1 three years must elapse before a former member of the Commission is eligible for re-election;

3.2.2. this provision [Art. 3.2.1] shall not apply when a retiring or former member is pre-elected by the Commission to continue as or to become its President if re-elected as a member.

[Article 3.3 is to be revised to exclude Article 3.3.1, which is to be deleted. Article 3.3.2 is to be renumbered as Article 3.3.1. Article 3.3.3 is to be revised and renumbered as Article 3.3.2]

3.3. Prior termination of membership.

The membership of any member of the Commission shall terminate prior to the expiration of the term of service under art. 3.1 above:

3.3.1. on acceptance by the Council of notice of resignation tendered in writing to the Executive Secretary;

3.3.2.. if, not being on leave of absence, he or she fails on five consecutive occasions to return the ballot, or, when no ballot is provided, fails to record a vote for or against or an abstention ~~to record a vote or an abstention~~ on questions put to the Commission for decision, provided that within a period of three months following such failure no written explanation has been made which the Council finds adequate.

Article 4. Election of members of the Commission.

[Article 4.1.1 is to be revised to specify "countries of residence" instead of "nationalities" in recognition of the fact that some Commissioners are expatriates. Article 4.1.2. is to be revised to specify "refers" instead of "quotes".]

4.1. Notice.

The Commission shall publish, not less than one year before a general session of the Commission [Art. 11.1], a notice which:

4.1.1. gives the names, countries of residence ~~nationalities~~ and fields of specialization of the members whose terms of service will end at the close of that session in accordance with Article 3;

4.1.2. ~~quotes~~ refers to Article 2.2 and invites nominations for membership of the Commission;

4.1.3. gives a date, not more than three months before the forthcoming general session, by which nominations must be received.

[Article 4.2 is to be revised to include web sites as, depending on circumstances, either mandated or optional outlets for information]

4.2. Circulation.

The notice specified in Article 4.1 shall be published on the Commission web site and submitted to IUBS (or to its successor body, if any), to the organizers of the Congress where the general session is to be held, and to appropriate journals and/or web sites in different parts of the world, with a request for its dissemination.

[Article 4.3 is revised to add "Executive" before "Secretary" for consistency.]

4.3. Nominations.

Nominations, accompanied by a statement of the fields of specialization and qualification under Article 2.2 of each nominee, are to be sent to the Executive Secretary of the Commission. Unless the nomination contains the information, the Executive Secretary shall require each nominee to give consent to the nomination and to provide a curriculum vitae, a list of publications and a statement of his or her nomenclatural experience.

[Article 4.6 is to be revised to delete "postal".]

4.6. By-elections.

The Commission may by a ~~postal~~ ballot fill vacancies arising from prior termination of membership [Art. 3.3], or which have not been filled by election at a session of the Section of Zoological Nomenclature [Art. 4.4.1], or which result from an increase in the number of members decided by the Commission in accordance with Article 2.1.

[Articles 5.2 and 5.3 are to be revised to add "Executive" before "Secretary"]

5.2. Between sessions.

It shall be the duty of a member of the Commission to vote, within the prescribed period, upon each question submitted to him or her for that purpose by the Executive Secretary.

5.3. Leave of absence.

A member of the Commission who is temporarily unable to perform his or her duties should apply through the Executive Secretary (if possible in advance) for leave of absence for a specified period.

[Article 6 is to be unchanged. Article 7.1 is to be revised to include "Executive" before "Secretary" and to include "or she" after "he".]

7.1. The Executive Secretary to the Commission is also the Secretary to the Council but neither he or she nor any other member of the Secretariat shall vote in its deliberations.

[Article 8 is to be unchanged. Article 9 is to be revised to remove references to a Secretary-General and the International Trust for Zoological Nomenclature. The appointment of the Secretary-General is to be covered more generally in revised Article 14.]

Article 9. Secretariat.

The Council may appoint an Executive Secretary for such a term and with such duties as may be fixed in the Bylaws. ~~A member of the Commission may be appointed similarly as Secretary-General.~~ The Executive Secretary may be an employee of an appropriate body ~~such as the International Trust for Zoological Nomenclature~~.

[Articles 10 and 11 are to be unchanged. Article 12.2 is to be revised to remove "postal", to include the Commission web site and to remove the necessity of submitting proposed amendments to the Constitution to multiple journals before voting on them. Article 12.2 is also to be revised to reduce the voting period from three months to two, in recognition of the faster transmission speed of electronic mail compared to postal mail.]

12.2. In cases involving the use of the plenary power or amendments to the Code or Constitution.

In such cases (see Articles 78 to 81 of the Code for the use of the plenary power and Article 16 of this Constitution for amendments to the Code or Constitution) an affirmative decision shall be deemed to have been taken only when two thirds of the votes validly cast in a ~~postal~~ vote lasting ~~three~~ two months are in favour of the proposal, and provided that notice of the proposal had been published in the *Bulletin of Zoological Nomenclature*, on the Commission web site and, only for the amendments to the Code, submitted for publication to at least two appropriate journals at least six months (in the case of amendments to the Code or Constitution, twelve months) prior to the vote.

[Articles 13 is to be revised to remove the reference to the International Trust for Zoological Nomenclature.]

Article 13. Financial arrangements.

The Commission when not prepared to raise or administer its own funds is empowered for such purposes to enter into a beneficent relationship with one or more bodies ~~such as the International Trust for Zoological Nomenclature~~, that undertake to act in accordance with the policy of the Commission and IUBS (or its successor body, if any). The Commission may terminate such a relationship at its discretion.

[Articles 14 is to be revised to include "Executive" before "Secretary" and to incorporate elements from Article 9.]

Article 14. Editorial duties of the Commission.

The Commission shall issue and, finances permitting, may itself publish various communications, to be prepared and edited in the office of the Executive Secretary, or by another person appointed for that purpose, under the guidance of the Council.

[Articles 14.3 is to be revised to delete redundant language.]

14.3. ~~Maintenance of~~ *Official Lists* and *Indexes*.

The Commission shall compile and maintain the undermentioned *Lists* and *Indexes*:

14.3.1. *Official List of Family-Group Names in Zoology;*
14.3.2. *Official List of Generic Names in Zoology;*
14.3.3. *Official List of Specific Names in Zoology;*
14.3.4. *Official Index of Rejected and Invalid Family-Group Names in Zoology;*
14.3.5. *Official Index of Rejected and Invalid Generic Names in Zoology;*
14.3.6. *Official Index of Rejected and Invalid Specific Names in Zoology; Constitution*
14.3.7. *Official List of Works Approved as Available for Zoological Nomenclature;*
14.3.8. *Official Index of Rejected and Invalid Works in Zoological Nomenclature.*

[A new Article 14.5 is to be added to specify the Commission's duties with regards to the *Official Register of Zoological Nomenclature*.]

14.5. *Official Register of Zoological Nomenclature* (ZooBank).

The Commission shall maintain ZooBank, the *Official Register of Zoological Nomenclature*.

[Article 15 is to be unchanged. Article 16.1.2 is to be revised to specify the time span as “twelve months” instead of “one year”. Articles 16.1.4 and 16.1.5 are to be revised to remove “postal”. Article 16.1.4 is to be revised to reduce the voting period from three months to two, in recognition of the faster transmission speed of electronic mail compared to postal mail.]

16.1.2. receive and consider comments from zoologists that are received within twelve months ~~one year~~ of the publication of the proposals;

16.1.4. vote on the proposed amendments (which may be modified in the light of the comments by zoologists and the Section) in a ~~postal~~ vote lasting two ~~three~~ months [Art. 12.2]*;*

16.1.5. submit the amendments subject to their approval by two thirds of the votes validly cast in the ~~postal~~ vote, and with the support of the Section for the major principles, to IUBS (or to its successor body, if any) for ratification [Art. 90 of the Code];

[Articles 17 is to be revised to distinguish between Bylaws and Procedures.]

Article 17. Bylaws and Procedures.

The Commission is empowered to adopt a set of Bylaws and of Procedures governing those of its regulations and activities not covered by the Constitution.

The Commission has authority to modify these Bylaws and Procedures by a majority vote as the occasion demands. The~~se~~ Bylaws will deal with such matters as the duties of the Officers, the methods by which nominations are to be obtained for vacancies on the Commission, the relations between the Commission and the Secretariat, and with other business matters of the Commission. The Procedures will deal with regulations concerning the treatment to be given to applications and the adoption of time schedules and priorities, and with other business matters of the Commission.

[Article 18 is to be unchanged.]

References

ICZN (1999a) The Constitution of the International Commission on Zoological Nomenclature. In: International Code of Zoological Nomenclature. Fourth Edition. The International Trust for Zoological Nomenclature, London, 264–271.

ICZN (1999b) International Code of Zoological Nomenclature. Fourth Edition. The International Trust for Zoological Nomenclature, London, 306 pp.

ICZN (2003) Declaration 44. Amendment of Article 74.7.3. Bulletin of Zoological Nomenclature 60: 1–263.

ICZN (2012) Amendment of Articles 8, 9, 10, 21 and 78 of the International Code of Zoological Nomenclature to expand and refine methods of publication. ZooKeys 219: 1–10. https://doi.org/10.3897/zookeys.219.3944

ICZN (2017) Declaration 45 – Addition of Recommendations to Article 73 and of the term "specimen, preserved" to the Glossary. Bulletin of Zoological Nomenclature 73: 96–97. https://doi.org/10.21805/bzn.v73i2.a2

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RESEARCH ARTICLE

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A new species of *Cosmocerca* (Nematoda, Ascaridomorpha) from the marine toad *Rhinella marina* (Linnaeus) (Anura, Bufonidae) in Australia

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Abstract

The marine toad *Rhinella marina* (Linnaeus) (Anura, Bufonidae) is a notorious, exotic amphibian species in Australia. However, our present knowledge of the composition of the nematode fauna of *R. marina* is still not complete. In the present study, a new cosmocercid nematode, *Cosmocerca multipapillata* **sp. nov.**, was described using both light and scanning electron microscopy, based on specimens collected from *R. marina* in Australia. *Cosmocerca multipapillata* **sp. nov.** can be easily distinguished from its congeners by the body size, the presence of lateral alae and well sclerotized gubernaculum, the number and arrangement of plectanes and rosettes and the length of spicules, oesophagus and tail.

Keywords

parasite, nematode, Ascaridida, Cosmocercoidea, marine toad *Rhinella marina*, new species, Australasian Region

Introduction

The marine toad *Rhinella marina* (Linnaeus) (Anura, Bufonidae) is a large, terrestrial toad, which is natively distributed in Central and South America (Zug and Zug 1979; Lever 2001). The species has been widely introduced to the United States, Fiji, Philippines, Papua New Guinea, Australia, Japan, the Caribbean and some Pacific islands for controlling agricultural pests (Alford et al. 1995; Frost 2016). The helminth fauna of *R. marina* was studied by many authors and over 30 species of nematode parasites have been recorded from this host (Brenes and Bravo-Hollis 1959; Speare 1990; Goldberg and Bursey 1992; Barton 1996; Bursey et al. 2000; Kuzmin et al. 2007; Espinoza-Jimenez et al. 2007; Bursey and Brooks 2010; Drake et al. 2014).

During a helminthological survey in Australian amphibians, some nematodes belonging to the Cosmocercoidea Travassos, 1925 were collected from *R. marina*. Their examination using light and scanning electron microscopy revealed that these specimens represented a new species of *Cosmocerca* Diesing, 1861.

Materials and methods

Light and scanning electron microscopy

Nematodes were collected from the intestine of the marine toad *R. marina* (Linnaeus) (Anura, Bufonidae) in various locations from Queensland, Australia. Specimens were fixed and stored in 70% ethanol until study. For light microscopy studies, nematodes were cleared in lactophenol. Drawings were made with the use of a Nikon microscope drawing attachment. For scanning electron microscopy (SEM), specimens were re-fixed in a 4% formaldehyde solution, post-fixed in 1% OsO4, dehydrated via an ethanol series and acetone, and then critical point dried. Samples were coated with gold and examined using a Hitachi S-4800 scanning electron microscope at an accelerating voltage of 20 kV. Measurements (the range, followed by the mean in parentheses) are given in micrometers (μm) unless otherwise stated. Type specimens were deposited in College of Life Sciences, Hebei Normal University, Hebei Province, China.

Results

***Cosmocerca multipapillata* sp. nov.**
http://zoobank.org/45496476-7E22-4A91-A0F5-E5CFFA7E9123
Figures 1–3

Description. Small-sized, whitish nematodes. Body cylindrical, maximum width at about region of mid-body. Cuticle with fine transverse striations. Excretory pore situated slightly anterior to esophageal bulb (Figs 1A, B, 2C). Deirids not observed. Somatic papillae present (Figs 2D, E, 3A, C). Oral aperture simple, somewhat triangular,

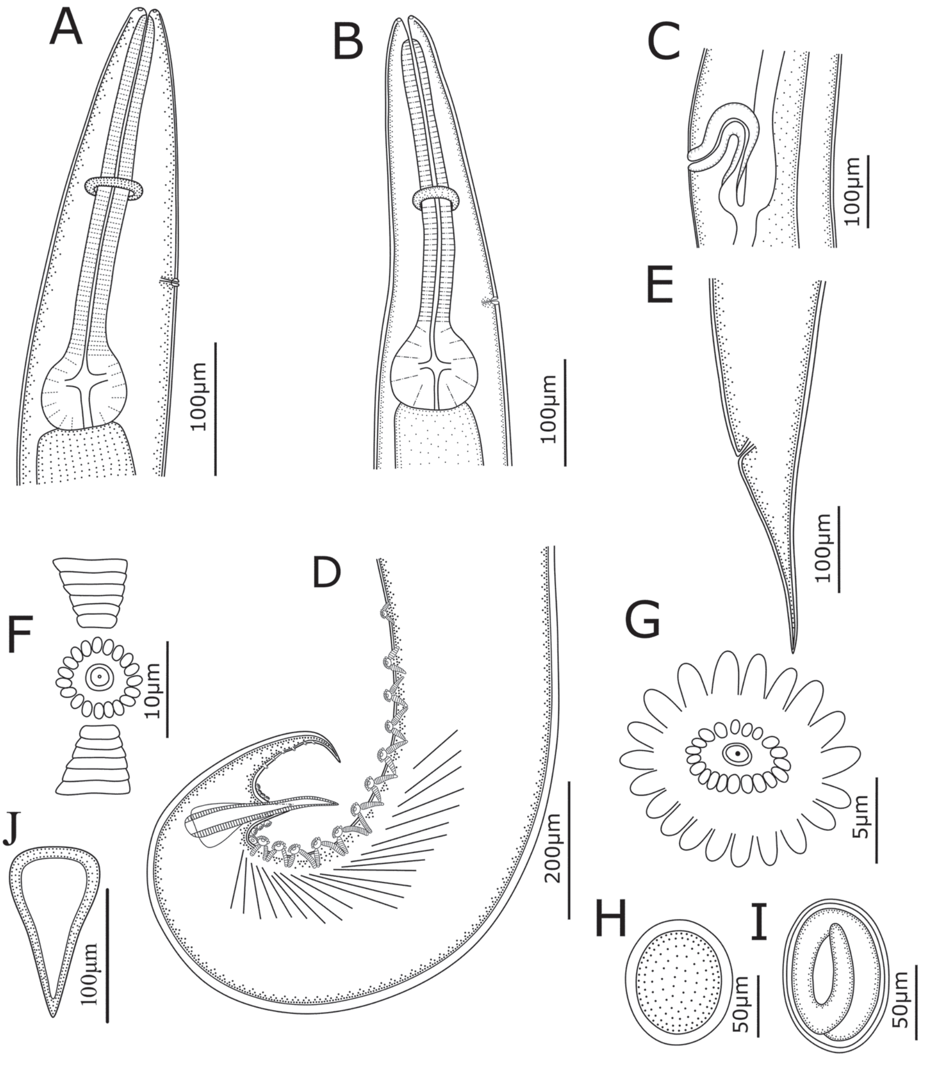

Figure 1. *Cosmocerca multipapillata* sp. nov. collected from the marine toad *Rhinella marina* (Linnaeus) (Anura: Bufonidae) in Australia. **A** anterior part of male, lateral view **B** anterior part of female, lateral view **C** region of vulva, lateral view **D** posterior end of male, lateral view **E** posterior end of female, lateral view **F, G** plectane **H, I** eggs **J** gubernaculum.

surrounded by 3 small lips (Fig. 2B). Dorsal lip with one pair of large double cephalic papillae, subventral lips with single large double cephalic papilla and amphid (Fig. 2B). Oesophagus divided into anterior indistinct pharynx, cylindrical corpus and terminal posterior bulb with valves (Fig. 1A, B). Nerve ring located at about 1/2 of oesophageal length. Tail of both sexes conical, with pointed tip (Figs 1D, E, 2E).

Male (based on 3 mature specimens): Body 3.10–3.55 (3.36) mm long; maximum width 248–327 (297). Oesophagus 365–479 (406) long (including bulb), representing 10.6–15.5 (12.2) % of body length; pharynx and corpus 288–385 (328) long, size of bulb

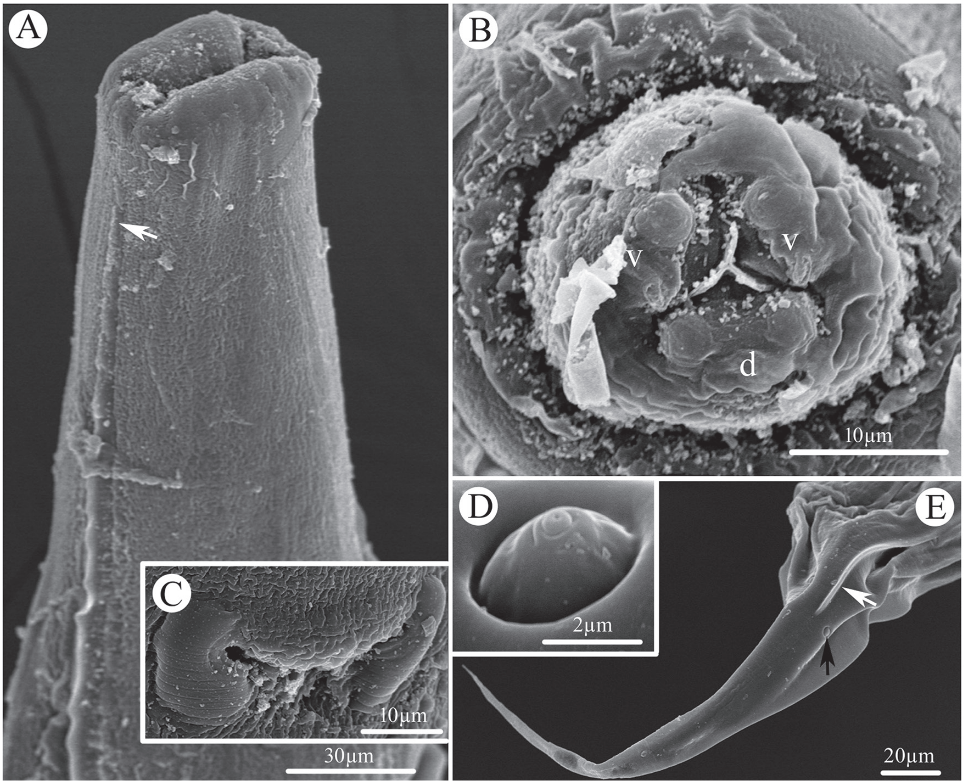

Figure 2. Scanning electron micrographs of female *Cosmocerca multipapillata* sp. nov collected from the marine toad *Rhinella marina* (Linnaeus) (Anura: Bufonidae) in Australia. **A** anterior part of body (lateral ala arrowed), ventrolateral view **B** cephalic end, apical view **C** magnified image of excretory pore **D** magnified image of somatic papilla **E** tail (lateral ala indicated by white arrow, somatic papilla indicated by black arrow), lateral view. Abbreviations: d, dorsal lip; v, ventrolateral lip.

65–94 (78.5) × 73–100 (83.3). Nerve ring 160–215 (196) and excretory pore 260–417 (323) from anterior extremity, respectively. Lateral alae narrow, extending from slightly posterior to cephalic end to level of third precloacal plectane (Fig. 2A). Posterior end of body distinctly ventrally curved (Figs 1D, 3A). Spicules alate, equal in length, 169–219 (185) long, distal end pointed (Figs 1D, 3C), representing 4.75–6.93 (5.53) % of body length. Gubernaculum small, well sclerotized, 125–146 (135) long (Fig. 1J). A total of 10–12 pairs of subventral precloacal plectanes and 3–4 pairs of precloacal rosettes present (Figs 1D, 3A). Each plectane consisting of a central papilla with two complete circles of 18–21 cuticular tubercles seated on underlying support of sclerotized segments (Figs 1F, G, 3D). Usually 3 pairs of subventral paracloacal and 1–2 pairs of postcloacal rosettes present (Figs 1D, 3A–C). Some pairs of small, sub-ventral and simple papillae (indistinguishable from somatic papillae) located at surface of postcloacal region (Fig. 3C). Tail 187–208 (201) long, representing 5.28–6.72 (6.03) % of body length (Fig. 1D).

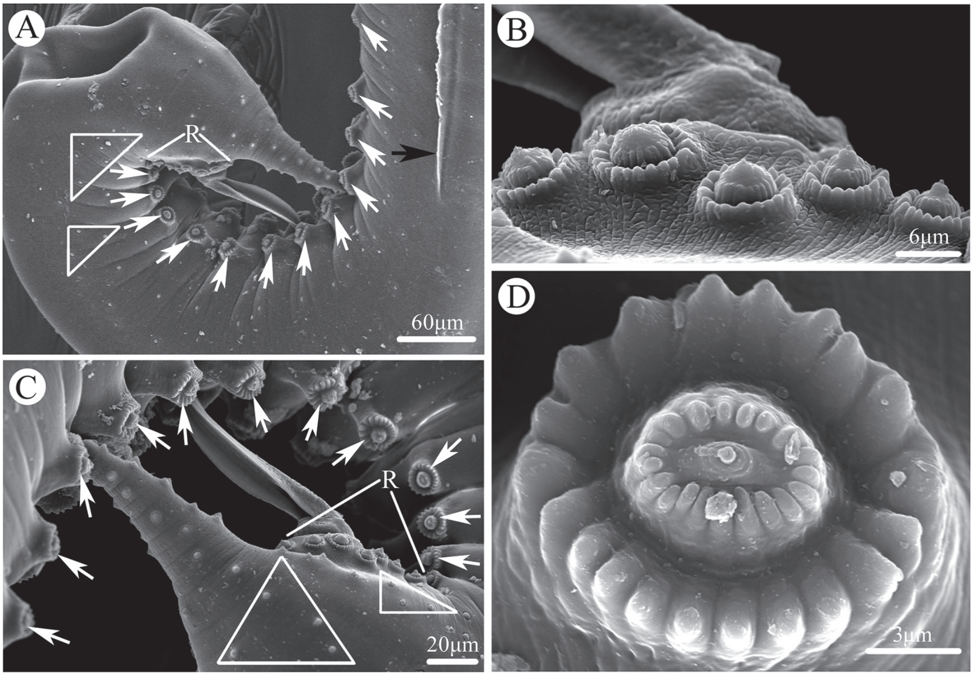

Figure 3. Scanning electron micrographs of male *Cosmocerca multipapillata* sp. nov. collected from the marine toad *Rhinella marina* (Linnaeus) (Anura: Bufonidae) in Australia. **A** posterior end of body (lateral ala indicated by black arrow, plectanes indicated by white arrows, somatic papillae indicated by triangle), sublateral view **B** magnified image of paracloacal rosettes **C** tail (plectanes indicated by white arrows, somatic papillae indicated by triangle), sub-dorsal view **D** magnified image of plectane. Abbreviation: R, rosettes.

Female (based on 10 mature specimens): Body 2.68–3.73 (3.23) mm long; maximum width 188–277 (232). Oesophagus 338–428 (376) mm long (including bulb), representing 9.08–12.8 (11.7) % of body length; pharynx and corpus 273–343 (194) long, size of bulb 56–94 (81.3) ×85–108 (97.3). Nerve ring 145–183 (164) and excretory pore 259–329 (281) from anterior extremity, respectively. Lateral alae extending from slightly posterior to cephalic end to level of about 1/2 length of tail. Vulval opening a transverse slit, vulval lips not protruded, 1.24–1.67 (1.45) mm from anterior extremity, at 41.6–53.4 (45.5) % of body length (Fig. 1C). Eggs oval, thin-walled with smooth surface, 66–108 (82.1) × 52–71 (61) (n = 20) (Fig. 1H, I). Tail 216–376 (292) long, representing 6.65–12.4 (9.42) % of body length (Fig. 1E).

Taxonomic summary

Type host. Marine toad *Rhinella marina* (Linnaeus) (Anura, Bufonidae).

Type locality. Bloomfield (approximately 180 km north of Cairns), northern Queensland, Australia.

Other localities. Cape Tribulation, Port Douglas, Abergowrie, Townsville region, all in northern Queensland, Australia.

Site of infection. Rectum.

Level of infection. 3.7% (24 out of 643) of *Rhinella marina* specimens were infected, with an intensity of 1–58 (mean 5.2) nematodes.

Type deposition. Holotype, male (HBNU–N-2019A024L); allotype, female (HBNU–N-2019A025L); paratypes: 2 males, 120 females (HBNU–N-2019A026L).

Etymology. The specific epithet is derived from a combination of the Latin words *multi-* (multiple) and *papillata* (bearing papillae), referring to the characteristic numerous pre-cloacal plectanes.

Discussion

Species of *Cosmocerca* (Ascaridida, Cosmocercoidea) mainly parasitize the digestive tract of various amphibians (Baker and Green 1988; Moravec and Baruš 1990; Moravec and Kaiser 1994; Rizvi et al. 2011; Sou and Nandi 2015; Sou et al. 2018). Bursey et al. (2015) listed 29 nominal species in this genus. Later, Sou et al. (2018) described a new species, *C. bengalensis* Sou, Sow & Nandi, 2018 from India. To date, a total of 30 species of *Cosmocerca* have been reported worldwide. Among these species, only three have been recorded in the Australasian Region, namely *C. archeyi* Baker & Green, 1988 and *C. australis* Baker & Green, 1988, both from *Leiopelma hochstetteri* Fitzinger (Anura, Leiopelmatidae) in New Zealand, and *C. limnodynastes* Johnson & Simpson, 1942 from *Limnodynastes dorsalis* (Gray) (Anura, Myobatrachidae) in Australia (Johnson and Simpson 1942; Baker and Green 1988; Bursey et al. 2015).

Cosmocerca multipapillata sp. nov. can be easily distinguished from the three above-mentioned species by having males with many more plectanes (10–12 pairs in the new species *vs* only 4–5 pairs in the other three) and a distinctly longer tail in females (0.22–0.38 mm, representing 6.65–12.4% of body length in the new species *vs* 0.14–0.22 mm, representing 3.25–6.33% of body length in the other three species) (Johnson and Simpson 1942; Baker and Green 1988; Bursey et al. 2015). Johnson and Simpson (1942) described *C. australiensis* Johnson & Simpson, 1942 and *C. propinqua* Johnson & Simpson, 1942 both from *L. dorsalis* in Australia. Both of them should be treated as *incertae sedis*, because only female specimens were found. In fact, Inglis (1968) considered that *C. australiensis* and *C. propinqua* should be transferred to *Parathelandros* Baylis, 1930 (Oxyurida, Pharyngodonidae) based on the morphological characters of the female. Nevertheless, the new species differs from *C. australiensis* and *C. propinqua* by the distinctly smaller body size in the female (2.68–3.73 mm in *C. multipapillata* sp. nov. *vs* 5.0–9.0 mm in the other two species). In addition, the position of the vulva and the morphology of the female tail of *C. multipapillata* sp. nov. are also different from *C. propinqua* (vulva situated in front of oesophageal bulb in this species). Moreover, the new species has a relatively longer oesophagus than that of *C. australiensis* (oesophageal length representing 9.08–12.8% of body length in *C. multipapillata vs* representing 3.89–4.67% of body length in *C. australiensis*) (Baker and Green 1988).

In the genus *Cosmocerca*, *C. ishaqi* (Islam, Farooq & Khanum, 1979) and *C. brasiliensis* Travassos, 1925 have 9 or more pairs of plectanes in males (Islam et al. 1979; Rizvi et al. 2011). *Cosmocerca multipapillata* sp. nov. is different from *C. ishaqi* by having a well sclerotized gubernaculum (0.13−0.15 mm long), the presence of lateral alae (*vs* gubernaculum and lateral alae absent in *C. ishaqi*) and relatively longer spicules (spicules 0.17−0.22 mm long, representing 4.75−6.93% of body length *vs* spicules 0.10 mm long, representing 3.42% of body length) (Islam et al. 1979). *Cosmocerca brasiliensis* was described from *Rhinella crucifer* (Wied) (Anura, Bufonidae), *Ischnocnema guentheri* (Steindachner) (Anura, Brachycephalidae), *Thoropa miliaris* (Spix) (Anura, Cycloramphidae) and *Boana faber* (Wied) (Anura, Hylidae) in Brazil (Travassos 1925, 1931). Dyer and Altig (1976) also reported this parasite in several species of frogs in Ecuador. *Cosmocerca brasiliensis* can be easily distinguished from the new species by having a much larger body size in females (9.0−12.7 mm long in the former *vs* 2.68−3.73 mm long in the latter), the absence of paracloacal rosettes and lateral alae (*vs* usually 3 pairs and presence of lateral alae in the new species), and a distinctly longer tail in females (0.53−0.74 mm long in *C. brasiliensis vs* 0.22−0.38 mm long in *C. multipapillata* sp. nov.).

Although some previous studies reported the marine toad *R. marina* harboring nematodes belonging to *Cosmocerca* (Speare 1990; Barton 1997; Espinoza-Jimenez et al. 2007), most of these studies did not identify the parasites to species level. Prior to this study, only *C. commutata* (Diesing, 1851), *C. podicipinus* Baker & Vicente, 1984, *C. brasiliensis* and *C. parva* Travassos, 1925 had been recorded in *R. marina* (Skrjabin et al. 1961; Bursey et al. 2001; Bursey and Brooks 2010). However, *C. commutata*, *C. parva* and *C. podicipinus* have only 4–7 pairs of precloacal plectanes (Skrjabin et al. 1961; Baker and Vicente 1984), which easily differentiates them from *C. multipapillata* sp. nov. (presence of 10–12 pairs of precloacal plectanes). The morphological differences between *C. brasiliensis* and *C. multipapillata* sp. nov. have been mentioned previously.

Based on morphological characters of the new species (i.e., the body size, the number of plectanes and the presence of well developed spicules and gubernaculum), we speculate that *C. multipapillata* sp. nov. could have been introduced to Australia along with its host *R. marina*, because all the recorded *Cosmocerca* species in the Australasian Region, including *C. archeyi*, *C. australis* and *C. limnodynastes*, have small body size (body length not over 2.00 mm in males), few plectanes (not over 5 pairs) and rudimental spicules and gubernaculum (Johnson and Simpson 1942; Baker and Green 1988; Bursey et al. 2015). However, some species of *Cosmocerca* found in the Neotropical Region have some common characters with the new species, for example, the body length of *C. brasiliensis*, *C. travasssosi* Rodrigues & Fabio, 1970, *C. cruzi* Rodrigues & Fabio, 1970 and *C. podicipinus* is more or less 3.0 mm or over 3.0 mm in males; *C. brasiliensis*, *C. uruguayensis* Lent & Freitas, 1948 and *C. vrcibradici* Bursey & Goldberg, 2004 all with many plectanes (7–9 pairs); *C. brasiliensis*, *C. rara* Freitas & Vicente, 1966 and *C. vrcibradici* with well developed spicules and/or gubernaculum (Lent and Freitas 1948; Freitas and Vicente 1966; Rodrigues and Fabio 1970; Bursey and Goldberg 2004). However, we need some more direct evidence to elucidate the origin of *C. multipapillata* sp. nov. in the Australasian Region or the Neotropical Region (i.e. if this new species is distributed in the Neotropical Region). Moreover, further studies on the composition of the *Cosmocerca* nematode fauna of native Australasian amphibians and rigorous phylogenetic studies to determine the interspecific relationships of *Cosmocerca* using genetic data including broad representatives worldwide (especially species from the Australasian and Neotropical Regions) are required to solve the evolutionary problem.

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References

Alford RA, Lampo M, Bayliss P (1995) The comparative ecology of *Bufo marinus* in Australia and South America. CSIRO *Bufo* Project: An Overview of Research Outcomes, Unpublished report, CSIRO, Australia.

Baker MR, Green DM (1988) Helminth parasites of native frogs (Leiopelmatidae) from New Zealand. Canadian Journal of Zoology 66: 707–713. https://doi.org/10.1139/z88-105

Barton DP (1996) The cane toad: A new host for helminth parasites in Australia. Australian Journal of Ecology 21: 114–117.

Barton DP (1997) Introduced animals and their parasites: The cane toad, *Bufo marinus* in Australia. Australian Journal of Ecology 22: 316–324. https://doi.org/10.1111/j.1442-9993.1997.tb00677.x

Brenes RR, Bravo-Hollis M (1959) Helmintos de la Republica de Costa Rica VIII. Nematoda 2. Algunos nematodes de *Bufo marinus marinus* (L) y algunas consideraciones sobre los ge´neros *Oxysomatium* y *Aplectana*. Revista de Biologia Tropical 7: 35–55.

Bursey CR, Brooks DR (2010) Nematode parasites of 41 anuran species from the Area de Conservacio' n Guanacaste, Costa Rica. Comparative Parasitology 77: 221–231. https://doi.org/10.1654/4418.1

Bursey CR, Goldberg SR (2004) *Cosmocerca vrcibradici* n. sp. (Ascaridida: Cosmocercidae), *Oswaldocruzia vitti* n. sp. (Strongylida: Molineidae), and other helminths from *Prionodactylus eigenmanni* and *Prionodactylus oshsaughnessyi* (Sauria: Gymnophthalmidae) from Brazil and Ecuador. Journal of Parasitology 90: 140–145. https://doi.org/10.1645/GE-3234

Bursey CR, Goldberg SR, Kraus F (2006) A new species of *Cosmocerca* (Nematoda: Cosmocercidae) and other helminths from *Genyophryne thomsoni* (Anura: Microhylidae) from Papua New Guinea. Acta Parasitologica 51: 213–216. https://doi.org/10.2478/s11686-006-0033-5

Bursey CR, Goldberg SR, Parmelee JR (2001) Gastrointestinal helminths of 51 species of anurans from Reserva Cuzco Amazonico, Peru. Comparative Parasitology 68: 21–25.

Bursey CR, Goldberg SR, Salgado-Maldonado G (2000) Helminths of two sympatric toad species, *Bufo marinus* (Linnaeus) and *Bufo marmoreus* Wiegmann, 1833 (Anura: Bufonidae) from Chamela, Jalisco, Mexico. Comparative Parasitology 67: 129–133.

Bursey CR, Goldberg SR, Siler CD, Brown RM (2015) A new species of *Cosmocerca* (Nematoda: Cosmocercidae) and other helminths in *Cyrtodactylus gubaot* (Squamata: Gekkonidae) from the Philippines. Acta Parasitologica 60: 675–681. https://doi.org/10.1515/ap-2015-0096

Drake MC, Zieger U, Groszkowski A, Gallardo B, Sages P, Reavis R, Faircloth L, Jacobson K, Lonce N, Pinckney R, Cole RA (2014) Survey of helminths, ectoparasites, and Chytrid fungus of an introduced population of cane toads, *Rhinella marina* (Anura: Bufonidae), from Grenada, West Indies. Journal of Parasitology 100: 608–615. https://doi.org/10.1645/13-470.1

Dyer WG, Altig R (1976) Redescription of *Cosmocerca brasiliensis* Travassos 1925 (Nematoda: Cosmocercidae) from Ecuadorian frogs. Journal of Parasitology 62: 262–264. https://doi.org/10.2307/3279281

Espinoza-Jiménez A, García-Prieto L, Osorio-Sarabia D, León-Règagnon V (2007) Checklist of helminth parasites of the cane toad *Bufo marinus* (Anura: Bufonidae) from Mexico. Journal of Parasitology 93: 937–944. https://doi.org/10.1645/GE-1047R.1

Freitas JFT, Vicente JJ (1966) Novo nematodeo do genero *Cosmocerca* Dising, 1861, parasito de anfisbaendeo. Atas Sociedade de Biologia do Rio de Janeiro 10: 109–111.

Frost DR (2016) Amphibian Species of the World: An Online Reference. Version 6.0. Electronic Database. American Museum of Natural History, New York, USA. http://research.amnh.org/herpetology/amphibia/index.html

Goldberg SR, Bursey CR (1992) Helminths of the Marine Toad, *Bufo marinus* (Anura: Bufonidae), from America Samoa. Journal of the Helminthological Society of Washington 59: 131–133.

Inglis WG (1968) Nematodes parasitic in western Australian frogs. Bulletin of the British Museum (National History), Zoology 16: 161–183.

Islam A, Farooq M, Khanum Z (1979) Two new genera of nematode parasites (Oxyuridae: Oxysomatinae) from toad, *Bufo andersoni*. Pakistan Journal of Zoology 11: 69–73.

Johnston TH, Simpson ER (1942) Some nematodes from Australian frogs. Transactions of the Royal Society of South Australia 66: 172–179.

Kuzmin Y, Tkach VV, Brooks DR (2007) Two new species of *Rhabdias* (Nematoda: Rhabdiasidae) from the marine toad, *Bufo marinus* (L.) (Lissampibia: Anura; Bufonidae), in Central America. Journal of Parasitology 93: 159–165. https://doi.org/10.1645/GE-858R.1

Lent H, Freitas JFT (1948) Uma colecao de Nematodeos, parasitos de vertebrados, do Museu de Historia Natural de Montevideo. Memorias do Instituto Oswaldo Cruz 46: 1–71. https://doi.org/10.1590/S0074-02761948000100001

Lever C (2001) The cane toad: The history and ecology of a successful colonist. Westbury Academic and Scientific Publishing, Otley, West Yorkshire, England, 289 pp.

Moravec F, Baruš V (1990) Some nematode parasites from amphibians and reptiles from Zambua and Uganda. Acta Societatis Zoologicae Bohemoslovacae 54: 177–192.

Moravec F, Kaiser H (1994) Description of *Cosmocerca longispicula* sp. nov. (Nematoda: Cosmocercidae), a parasite of a dendrobatid frog from Martinique, French Antilles. Parasitology Research 80: 29–32.

Rizvi AN, Bursey CR, Bhutia PT (2011) *Cosmocerca kalesari* sp. nov. (Nematoda, Cosmocercidae) in *Euphlyctis cyanophlyctis* (Amphibia, Anura) from Kalesar Wildlife Sanctuary, Haryana, India. Acta Parasitologica 56: 202–207. https://doi.org/10.2478/s11686-011-0028-8

Rodrigues HO, Fabio SP (1970). Nova especie do genero *Cosmocerca* Diesing, 1861 (Nematoda, Oxyuroidea). Atas da Sociedade de Biologia do Rio de Janeiro 13: 179–180.

Skrjabin KI, Shikhobalova NP, Lagodovskaya EA (1961) Oxyurata of animals and man. Part Two, Translated from Russian. Israel Program for Scientific Translations, Jerusalem, Israel, 1974: 460 pp.

Sou SK, Nandi AP (2015) On a new species of *Cosmocerca* (Nematoda; Cosmocercidae) from *Microhyla rubra* (Anura: Microhylidae) from West Bengal, India. Acta Parasitologica 60: 261–265. https://doi.org/10.1515/ap-2015-0037

Sou SK, Sow KK, Nandi AP (2018) *Cosmocerca bengalensis* sp. nov. (Nematoda: Cosmocercidae) in *Hoplobatrachus tigerinus* (Daudin, 1803) (Amphibia, Anura, Dicroglossidae) from West Bengal, India. Acta Parasitologica 63: 715–720. https://doi.org/10.1515/ap-2018-0084

Speare R (1990) A review of the diseases of the cane toad, *Bufo marinus*, with comments on biological control. Australian Wildlife Research 17: 387–410. https://doi.org/10.1071/WR9900387

Travassos L (1925) Contribuicoes para o conhecimento da fauna helmintologica dos batrachios do Brasil. Nematodeos intestinais. Science and Medicine 3: 673–687.

Travassos L (1931) Pesquisas helmintólogicas realizadas em Hamburgo. IX. Ensaio monographico da familia Cosmocercidae Trav., 1925 (Nematoda). Memórias do Instituto Oswaldo Cruz 25: 237–298. https://doi.org/10.1590/S0074-02761931000300003

Zug GR, Zug PB (1979) The marine toad, *Bufo marinus*: A natural history resume of native populations. Smithsonian Contributions to Zoology 284: 1–58. https://doi.org/10.5479/si.00810282.284

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RESEARCH ARTICLE

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A new genus and two new species of oonopid spiders from Myanmar (Araneae, Oonopidae)

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Abstract

A new genus, *Promolotra* **gen. nov.**, including two new species, *P. hponkanrazi* **sp. nov.** (♂♀) and *P. shankhaung* **sp. nov.** (♂), is described from Myanmar. The new genus is similar to *Molotra* Ubick & Griswold, 2011 but can be distinguished by the completely fused bulb and cymbium, the presence of a receptacle, the absence of grooves connecting either the anterior or posterior pairs of spiracles, and the incised labium of both sexes.

Keywords

Goblin spiders, new genus, new species, Southeast Asia, taxonomy

Introduction

Oonopidae is a diverse spider family with 1846 extant described species in 113 genera (Li 2020). They have a nearly worldwide distribution, occurring mainly in the leaf litter, under bark, and in the tree canopy (Jocqué and Dippenaar-Schoeman 2006; Ubick and Dupérré 2017). Several new oonopid genera of Southeast Asia have been erected in recent years. For example, *Aposphragisma* Thoma, 2014 from Indonesia, Malaysia, Singapore and Vietnam, *Prethopalpus* Baehr et al., 2012 from Indonesia, Malaysia and Singapore, *Sicariomorpha* Ott & Harvey, 2015 from Malaysia, and *Vientianea* Tong & Li, 2013 from Laos (Baehr et al. 2012; Tong and Li 2013; Thoma et al. 2014; Ott et al. 2015). The oonopid fauna of Myanmar has been poorly studied. Up to now, eight species have been reported from Myanmar, i.e., *Gamasomorpha inclusa* (Thorell, 1887), *G. psyllodes* Thorell, 1897, *G. sculptilis* Thorell, 1897, *Kachinia mahmolae* Tong & Li, 2018, *K. putao* Tong & Li, 2018, *Opopaea kanpetlet* Tong & Li, 2020, *O. zhigangi* Tong & Li, 2020, and *Xestaspis parmata* Thorell, 1897 (Tong et al. 2018, 2020; WSC 2020). In this paper, a new oonopid genus and two new species collected from Myanmar, are described and illustrated.

Materials and methods

The specimens were examined using a Leica M205C stereomicroscope. Details were studied under an Olympus BX51 compound microscope. Photos were made with a Canon EOS 550D zoom digital camera (18 megapixels) mounted on an Olympus BX51 compound microscope. Vulvae were cleared in lactic acid. Scanning electron microscope images (SEM) were taken under high vacuum with a Hitachi TM3030 after critical point drying and gold-palladium coating. All measurements were taken using an Olympus BX51 compound microscope and are in millimeters. The type material is deposited in the Institute of Zoology, Chinese Academy of Sciences in Beijing (IZCAS).

The following abbreviations are used in the text and figures: ALE = anterior lateral eyes; ap = apodeme; bls = brush-like structures; dl = dorsal lobe; hss = horseshoe-shaped sclerite; ldi = labium deep incision; pl = posterior lobe; PLE = posterior lateral eyes; PME = posterior median eyes; pr = posterior receptaculum; tls = tube-like structure; tsc = T-shaped sclerite; vl = ventral lobe.

Taxonomy

***Promolotra* gen. nov.**

http://zoobank.org/66FBE56C-1887-4984-8DB7-5D50FEAA5371

Type species. *Promolotra shankhaung* sp. nov.

Etymology. The generic name refers to the similarities of this genus and *Molotra* and is feminine in gender.

Diagnosis. *Promolotra* gen. nov. resembles *Molotra* Ubick & Griswold, 2011 (Ubick and Griswold 2011) by the heavily sclerotized dorsal and ventral abdominal scuta, the long spines on legs I and II, and the embolar region, but can be distinguished by the completely fused bulb and cymbium, the presence of a receptacle, the absence of grooves connecting either the anterior or posterior pairs of spiracles, and the incised labium of both sexes. The new genus is also similar to *Costarina* Platnick & Dupérré, 2011 by the heavily sclerotized dorsal and ventral abdominal scuta, the long spines on legs I and II, the absence of grooves connecting either the anterior or posterior pairs of spiracles, and the fused cymbium and bulb, but can be distinguished by the absence of 3 transverse ridges on the sternum, the embolar region which barely extends beyond the tip of the cymbiobulbus, and the incised labium of both sexes. The genus *Costarina* has 3 transverse ridges on the sternum, the embolar region is divided into two black prongs that distinctly extend beyond the tip of the cymbiobulbus, and the labium is not indented at the anterior margin (Platnick and Dupérré 2012).

Description. Male. Body yellow-brown, legs yellow. Carapace (Figs 1A, 5A): broadly oval in dorsal view, without any pattern; pars cephalica slightly elevated in lateral view, with rounded posterolateral corners, posterolateral edge without pits, posterior margin not bulging below posterior rim, anterolateral corners without extensions or projections, posterolateral surface without spikes, surface of pars cephalica smooth, thorax without depressions, fovea absent, without radiating rows of pits; lateral margin straight, rebordered, with small blunt denticles; marginal setae present. Eyes (Figs 1A, E, 5A, E): 6, well-developed, arranged in a compact group; ALE largest, PME, PLE subequal; ALE separated by nearly more than their radius, ALE–PLE separated by less than ALE radius, PME touching each other; posterior row recurved from above, procurved from front. Clypeus (Figs 1E, 5E): margin unmodified, sinuous in front view, vertical in lateral view; ALE separated from edge of carapace by 2 times their diameter. Chilum absent. Mouthparts (Figs 3A–F, 7A–F): chelicerae straight, anterior face strongly swollen, with cone-shaped protuberance in lateral view (Figs 1G, 3C, 5G, 7C); with large tooth on promargin; labium rectangular, anterior margin deeply incised (ldi), same as sternum in sclerotization, not fused to sternum; endites with distal excavation, posteromedian part unmodified, same as sternum in sclerotization. Sternum (Figs 1B, 5D): uniformly orange-brown, not fused to carapace, median concavity absent; longer than wide, with radial furrows between coxae, surface smooth, covered with small, round pits, anterior margin unmodified, posterior margin not extending posteriorly of coxae IV, anterior corner unmodified, distance between coxae approximately equal, lateral margins unmodified, without posterior hump; setae sparse, dark, needlelike, evenly scattered, without hair tufts. Abdomen (Figs 1B, C, 5A–C): ovoid, rounded posteriorly; booklung covers large, brown, without setae, anterolateral edge unmodified; pedicel tube medium-sized, ribbed, scutum not extending far beyond dorsum of pedicel, lacking plumose hairs. Sperm pore small, oval, rebordered, situated between anterior and posterior spiracles; anterior and posterior spiracles not connected by grooves. Dorsal scutum strongly sclerotized, orange-brown, without pattern, covering full length of abdomen, no soft tissue visible from above, separate from epigastric scutum. Epigastric scutum strongly sclerotized, surrounding pedicel. Postgastric scutum strongly sclerotized, covering nearly full length of abdomen, fused to epigastric scutum, anterior margin unmodified, with posteriorly directed lateral apodemes. Spinneret scutum present as incomplete ring, with fringe of setae. Colulus represented only by setae. Legs (Figs 1D, 4H–K, 7G–J): yellowish brown, with brown pattern on basal part of tibiae in *P. shankhaung* sp. nov.; patella plus tibia I shorter than carapace. Trichobothria - tibia: each with 3; metatarsus: each with 1. Leg spines: tibiae I–II with 4 pairs of ventral spines; metatarsi I–II with 2 pairs of ventral spines, legs III and IV without spines. Palp (Figs 1H–J, 2, 5H–J, 6): normal size, weakly sclerotized, right and left palps symmetrical, uniformly pale orange. Trochanter unmodified; femur normal size, 3 or more times as long as trochanter; patella shorter than femur, without prolateral row of ridges. Cymbium completely fused with bulb, not extending beyond distal tip of bulb. Embolar region (Figs 2E, F, H, 6D, E, F, H) consists of 3 broad lobes and brush-like structures.

Female. As in male except as noted. Abdomen (Fig. 4E): postgastric scutum rectangular, not fused to epigastric scutum. Copulatory organ: surface with conspicuous genital atrium (Fig. 3G, H). Dorsal view (Fig. 4G) with a T-shaped sclerite (tsc) anteriorly, followed posteriorly by a narrow posterior receptaculum (pr); lateral apodemes (ap) present.

Composition. *P. hponkanrazi* sp. nov. (♂♀) and *P. shankhaung* sp. nov. (♂).

Distribution. Myanmar (Kachin State).

***Promolotra shankhaung* sp. nov.**

http://zoobank.org/A21E734C-1501-4AB5-9906-B0CFB717874B

Figures 1–4

Type materials. ***Holotype*** ♂ (IZCAS Ar-25131), Myanmar, Kachin State, Putao, roadside between Upper Shankhaung Village to Wasadum, secondary forest, 27°27.383'N, 97°13.650'E, elevation ca 1396 m, 11.XII.2016, J. Wu, by hand. ***Paratypes*:** 1♂, 1♀ (IZCAS Ar-25132-25133), same data as holotype; 1♂ (IZCAS Ar-25134), same data as holotype; 1♂, 1♀ (IZCAS Ar-25135-25136), Myanmar, Kachin State, Putao, roadside between Upper Shankhaung Village to Wasadum, 27°28.350'N, 97°12.850'E, elevation ca 1140 m, 11.XII.2016, J. Wu, by hand; 1♀ (IZCAS Ar-25137), Myanmar, Kachin State, Putao, Hponkanrazi Wildlife Sactuary, near Ziradum Village, 27°35.305'N, 97°04.893'E, elevation ca 1145 m, 13.V.2017, J. Wu and Z. Chen, by hand.

Etymology. The specific name is a noun in apposition taken from the type locality.

Diagnosis. The new species is similar to *P. hponkanrazi* sp. nov. (known from male only), but can be distinguished by the dark proximal part of the tibiae (Fig. 1D) (vs. uniformly colored in *P. hponkanrazi* sp. nov.), the relatively narrow ventral lobe (length/width = 2.4) of the embolar region (Fig. 2E) (vs. length/width of ventral lobe = 2.0 in *P. hponkanrazi* sp. nov.), and the shape of the cymbiobulbus (length/width = 1.7, basal part smooth) (Figs 1H, J, 2A) (vs. length/width of cymbiobulbus = 1.5 with basal part strongly swollen in *P. hponkanrazi* sp. nov.).

Description. Male (holotype). Habitus as in Fig. 1A–C. Body length 1.95; carapace 0.96 long, 0.74 wide; abdomen 0.89 long, 0.72 wide.

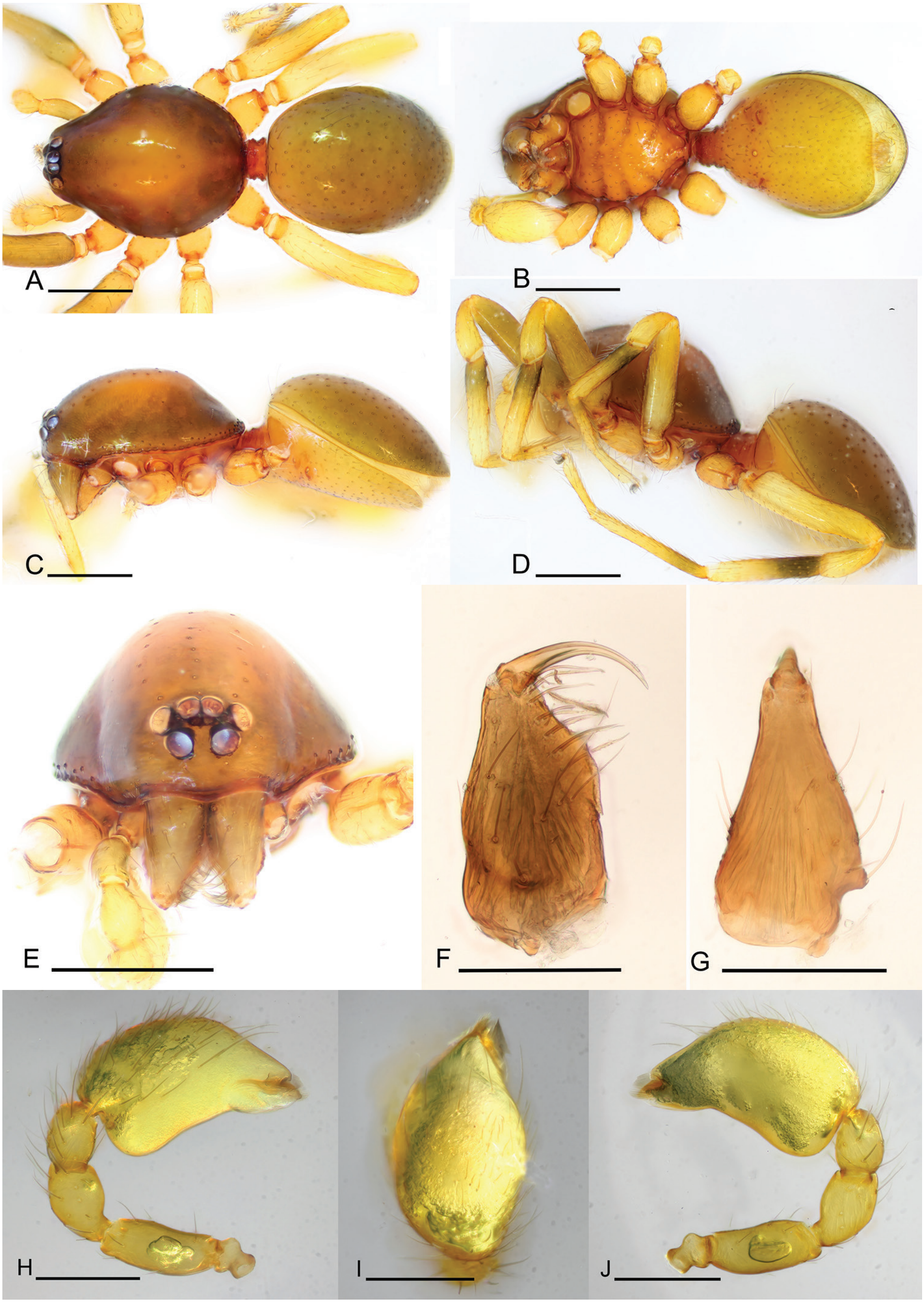

Figure 1. *Promolotra shankhaung* sp. nov., male **A–D** habitus, dorsal, ventral, and lateral views (**D** shows the leg color pattern) **E** prosoma, anterior view **F, G** left chelicera, anterior and lateral views **H–J** left palp, prolateral, dorsal, and retrolateral views. Scale bars: 0.4 mm (**A–E**); 0.2 mm (**F–J**).

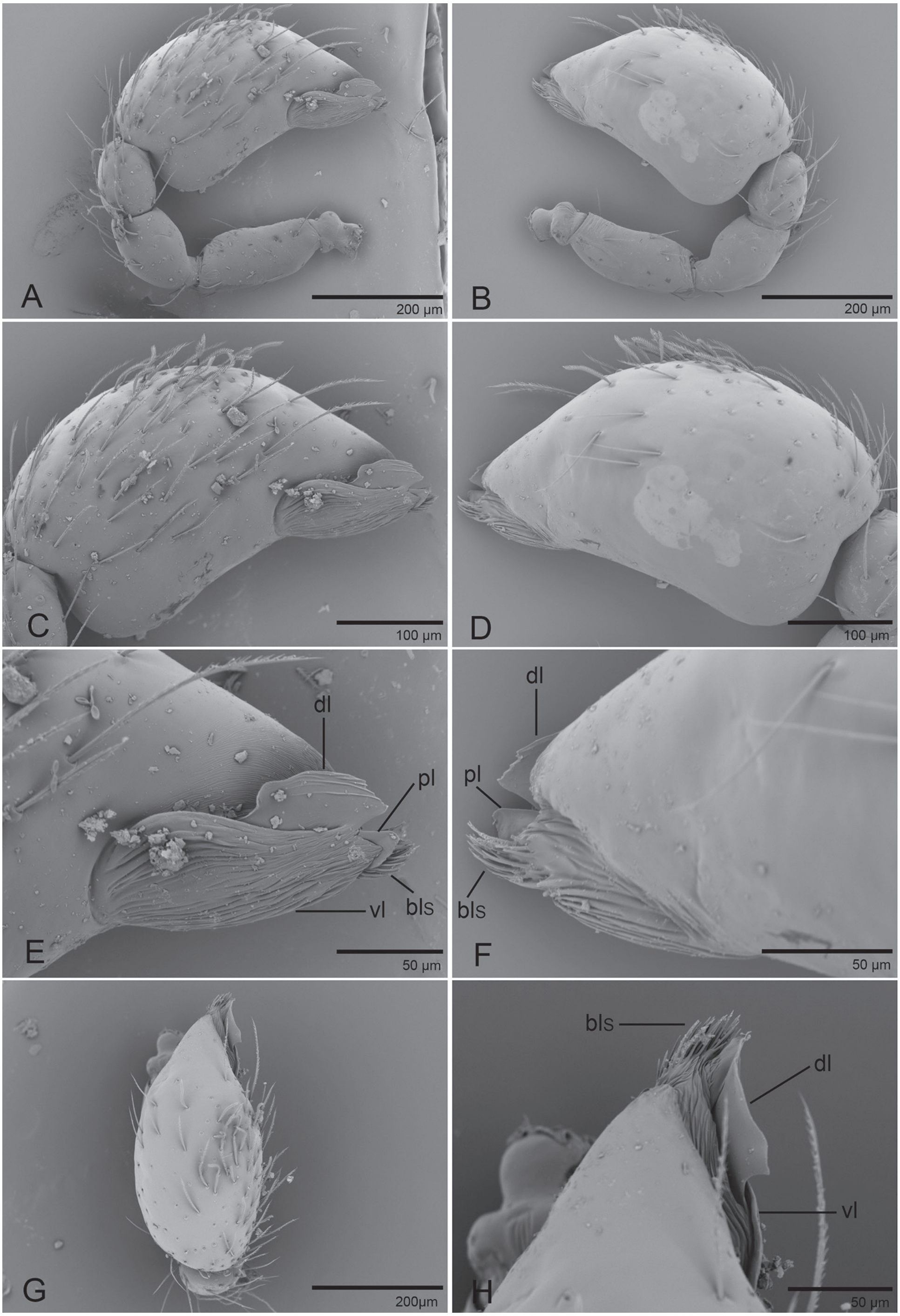

Figure 2. *Promolotra shankhaung* sp. nov., male left palp, SEM **A, B** prolateral and retrolateral views **C, D, G** cymbiobulbus, prolateral, retrolateral, and dorsal views **E, F, H** distal part of cymbiobulbus, prolateral, retrolateral, and dorsal views. Abbreviations: bls = brush-like structures; dl = dorsal lobe; pl = posterior lobe; vl = ventral lobe.

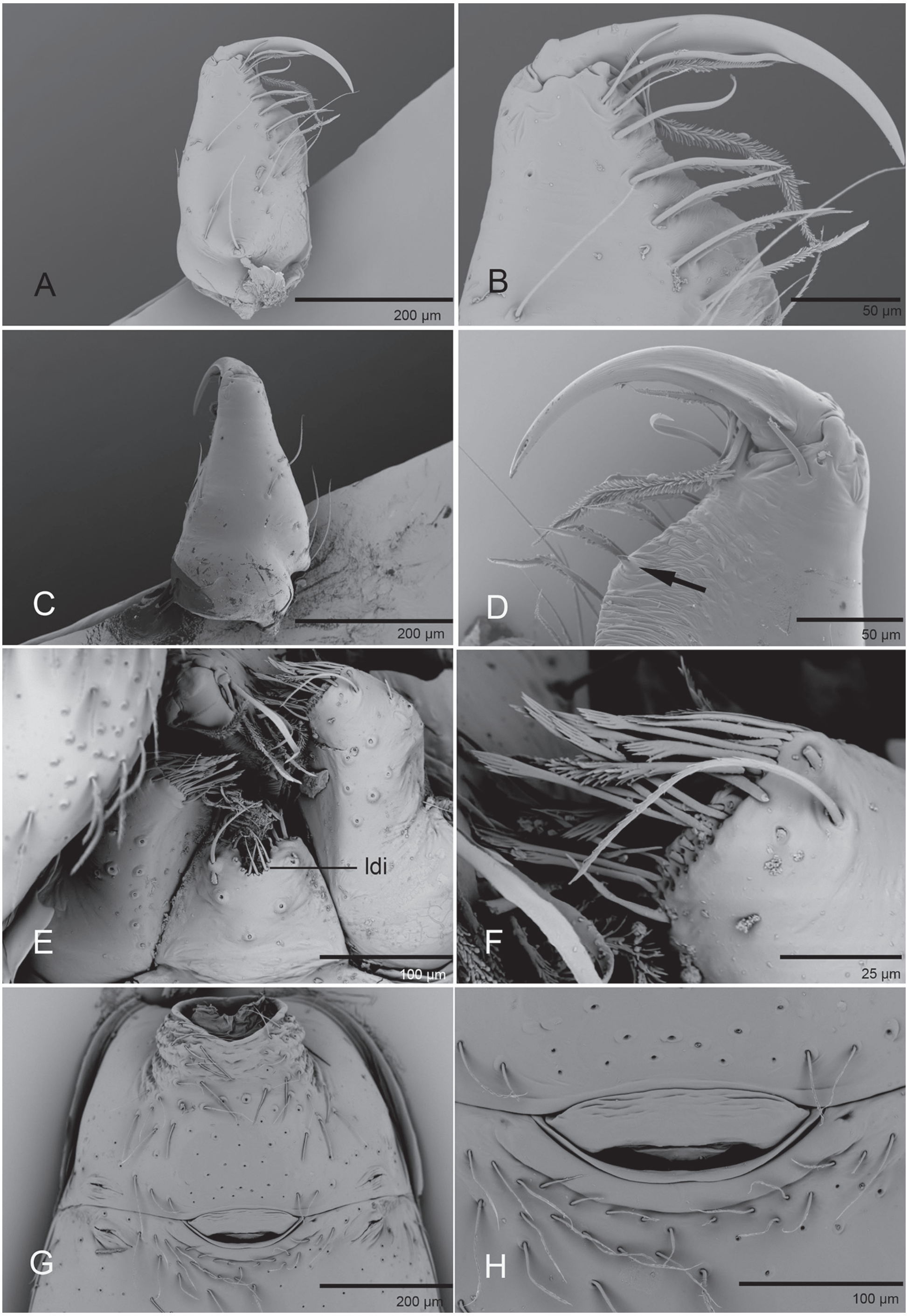

Figure 3. *Promolotra shankhaung* sp. nov. **A–F** male **G, H** female, SEM **A, C** left chelicera, anterior and lateral views **B, D** left chelicera, anterior and posterior magnified views (arrow shows the large denticle) **E** labium and endites, ventral view **F** endite, ventral view **G, H** copulatory organ, ventral view. Abbreviation: ldi = labium deep incision.

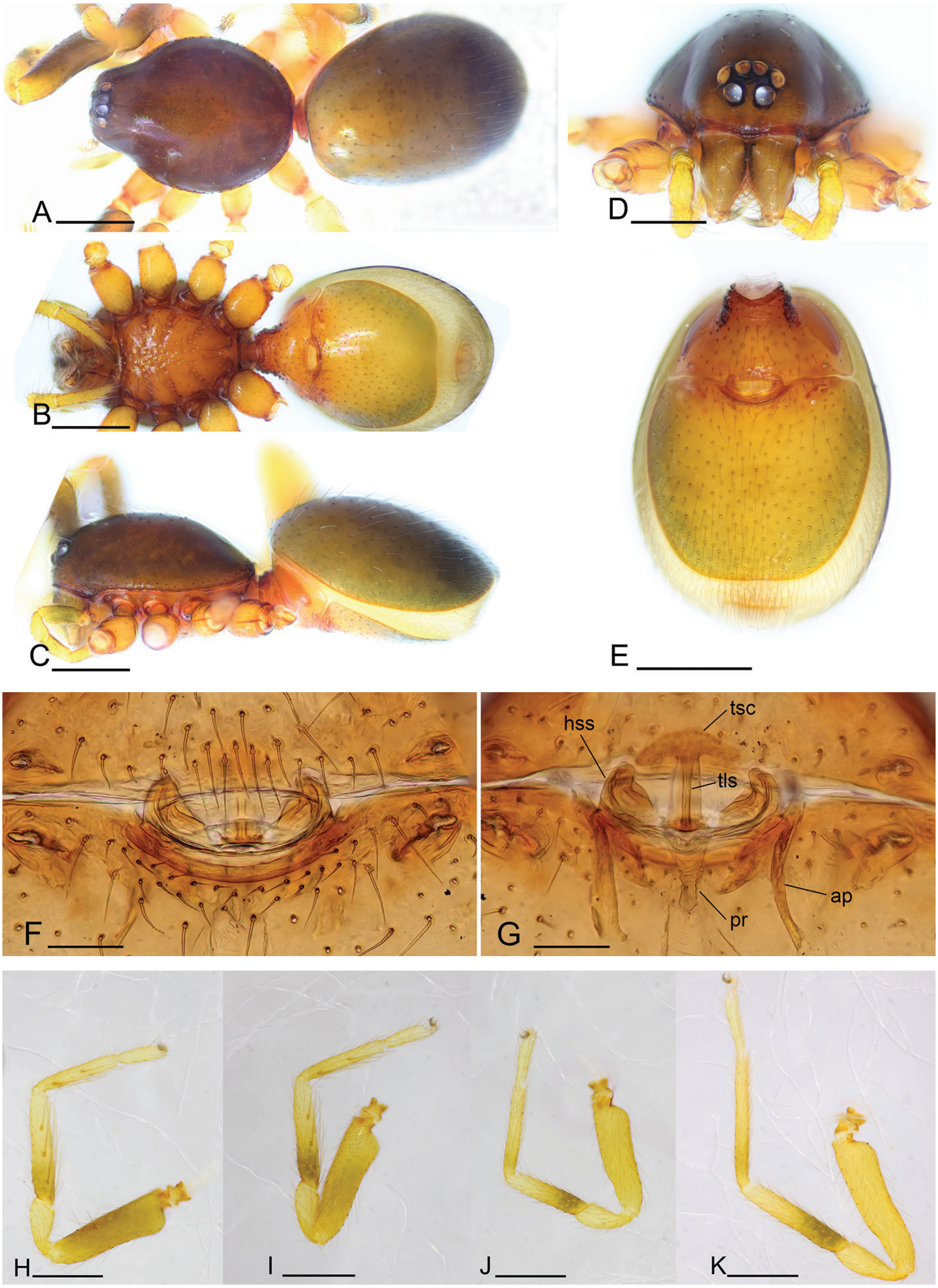

Figure 4. *Promolotra shankhaung* sp. nov. **A–G** female **H–K** male **A–C** habitus, dorsal, ventral, and lateral views **D** prosoma, anterior view **E** abdomen, ventral view **F, G** copulatory organ, ventral and dorsal views **H–K** left legs I–IV, prolateral view. Abbreviations: ap = apodeme; hss = horseshoe-shaped sclerite; pr = posterior receptaculum; tls = tube-like structure; tsc = T-shaped sclerite. Scale bars: 0.4 mm (**A–C, E, H–K**); 0.2 mm (**D**); 0.1 mm (**F, G**).

Palp (Figs 1H–J, 2): femur 0.19 long, patella 0.13 long, tibia 0.12 long. Cymbiobulbus 0.38 long, 0.22 wide, length/maximal width = 1.7. Embolar region (Fig. 2E, F, H): including a flat dorsal lobe (dl), a small posterior one (pl), and a narrow (length/width = 2.4), leaf-like, wrinkled texture ventral one (vl); with brush-like structures (bls) in retrolateral view.

Female. Habitus as in Fig. 4A–C. Body length 2.23; carapace 1.01 long, 0.91 wide; abdomen 1.17 long, 0.85 wide.

Copulatory organ. Ventral view (Figs 3G, H, 4F): genital atrium relatively wide, broadly oval. Dorsal view (Fig. 4G): with a T-shaped sclerite (tsc) anteriorly, followed posteriorly by a narrow posterior receptaculum (pr); a very thin, long and tube-like structure (tls) can be seen inside the T-shaped sclerite; with a horseshoe-shaped sclerite (hss) medially; apodemes (ap) well-developed.

Distribution. Known only from the type locality.

***Promolotra hponkanrazi* sp. nov.**

http://zoobank.org/630E87B0-7B79-4531-93C3-85421EEEAA0F

Figures 5–7

Type materials. ***Holotype*** ♂ (IZCAS Ar-25138), Myanmar, Kachin State, Putao, Hponkanrazi Wildlife Sactuary, secondary forest, 27°36.867'N, 96°58.933'E, elevation ca 2491 m, 15.XII.2016, J. Wu, by hand.

Etymology. The specific name is a noun in apposition taken from the type locality.

Diagnosis. The new species is similar to *P. shankhaung* sp. nov. but can be distinguished by the uniformly colored tibiae (Figs 5E, 7G–J) (vs. darkened proximally in *P. shankhaung* sp. nov.), the relatively broad ventral lobe (length/width = 2.0) of embolar region (Fig. 6E) (vs. length/width of ventral lobe = 2.4 in *P. shankhaung* sp. nov.), and the shape of the cymbiobulbus (length/width = 1.5, basal part strongly swollen) (Figs 5H, J, 6A) (vs. length/width of cymbiobulbus = 1.7 and the basal part smooth in *P. shankhaung* sp. nov.).

Description. Male (holotype). Habitus as in Fig. 5A–C. Body length 2.26; carapace 1.09 long, 0.85 wide; abdomen 1.13 long, 0.77 wide.

Palp (Figs 5H–J, 6): femur 0.26 long, patella 0.19 long, tibia 0.14 long. Cymbiobulbus 0.42 long, 0.28 wide, length/maximal width = 1.5. Embolar region (Fig. 6D, E, F, H): including a flat, dorsal lobe (dl), a very small posterior one (pl), and a very broad (length/width = 2.0), leaf-like, elongated, wrinkled texture ventral one (vl); with brush-like structures (bls) in retrolateral view.

Female. Unknown.

Distribution. Known only from the type locality.

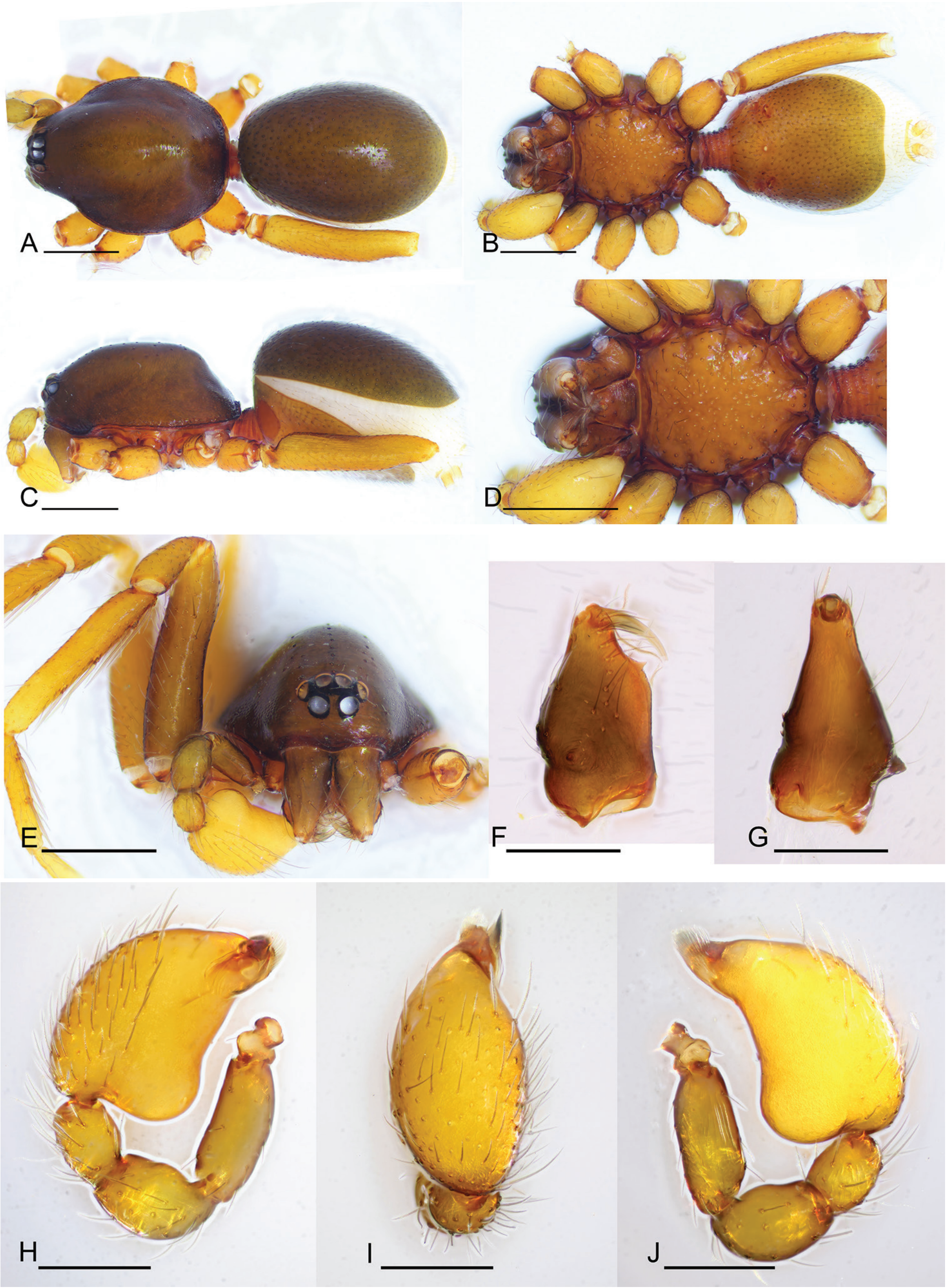

Figure 5. *Promolotra hponkanrazi* sp. nov., male **A–C** habitus, dorsal, ventral, and lateral views **D** prosoma, ventral view **E** prosoma, anterior view **F, G** left chelicera, anterior and lateral views **H–J** left palp, prolateral, dorsal, and retrolateral views. Scale bars: 0.4 mm (**A–E**) ; 0.2 mm (**F–J**).

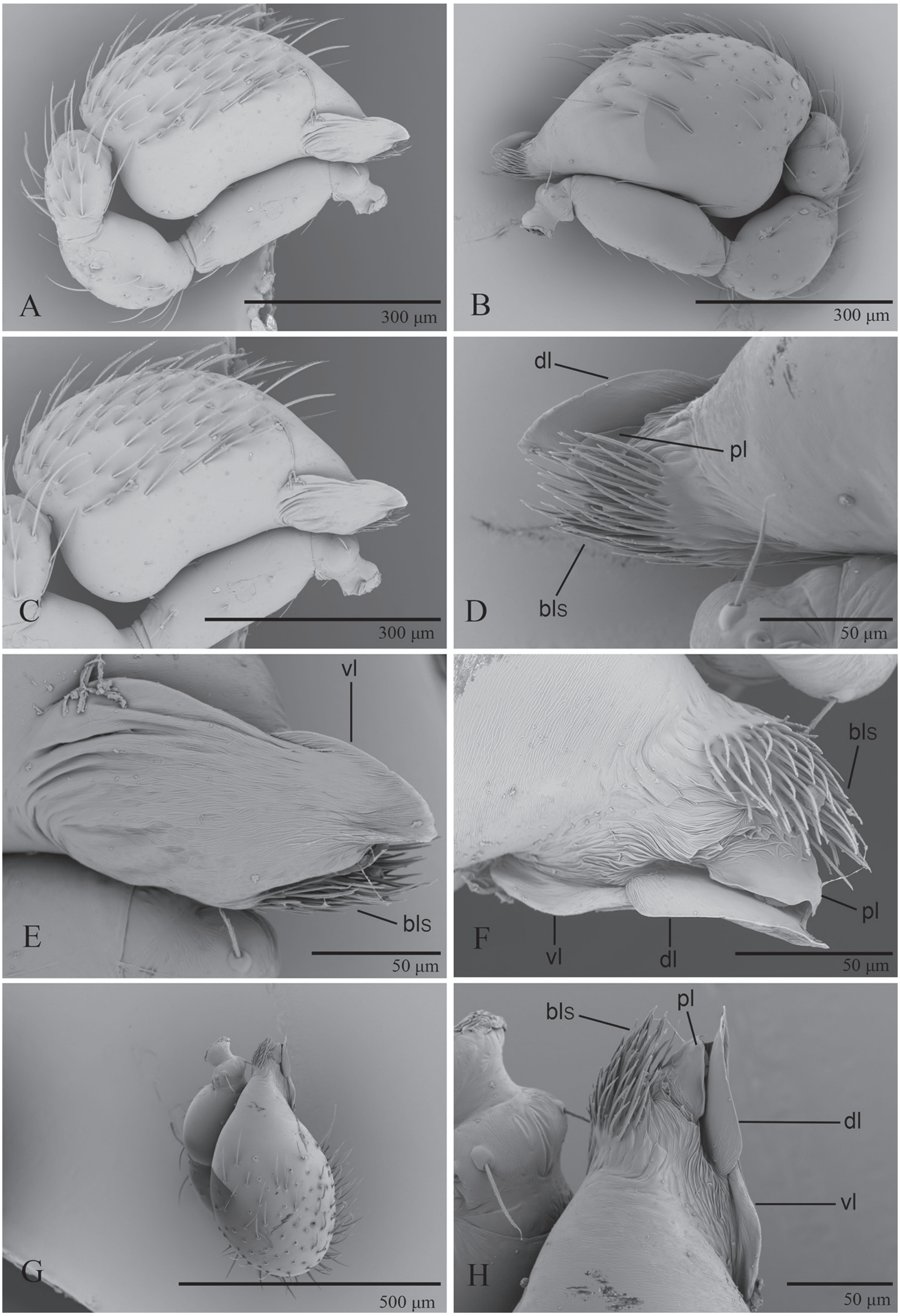

Figure 6. *Promolotra hponkanrazi* sp. nov., male left palp, SEM **A, B** prolateral and retrolateral views **C, G** cymbiobulbus, prolateral and dorsal views **D, E, H** distal part of cymbiobulbus, retrolateral, prolateral, and dorsal views **F** distal part of cymbiobulbus, apical view. Abbreviations: bls = brush-like structures; dl = dorsal lobe; pl = posterior lobe; vl = ventral lobe.

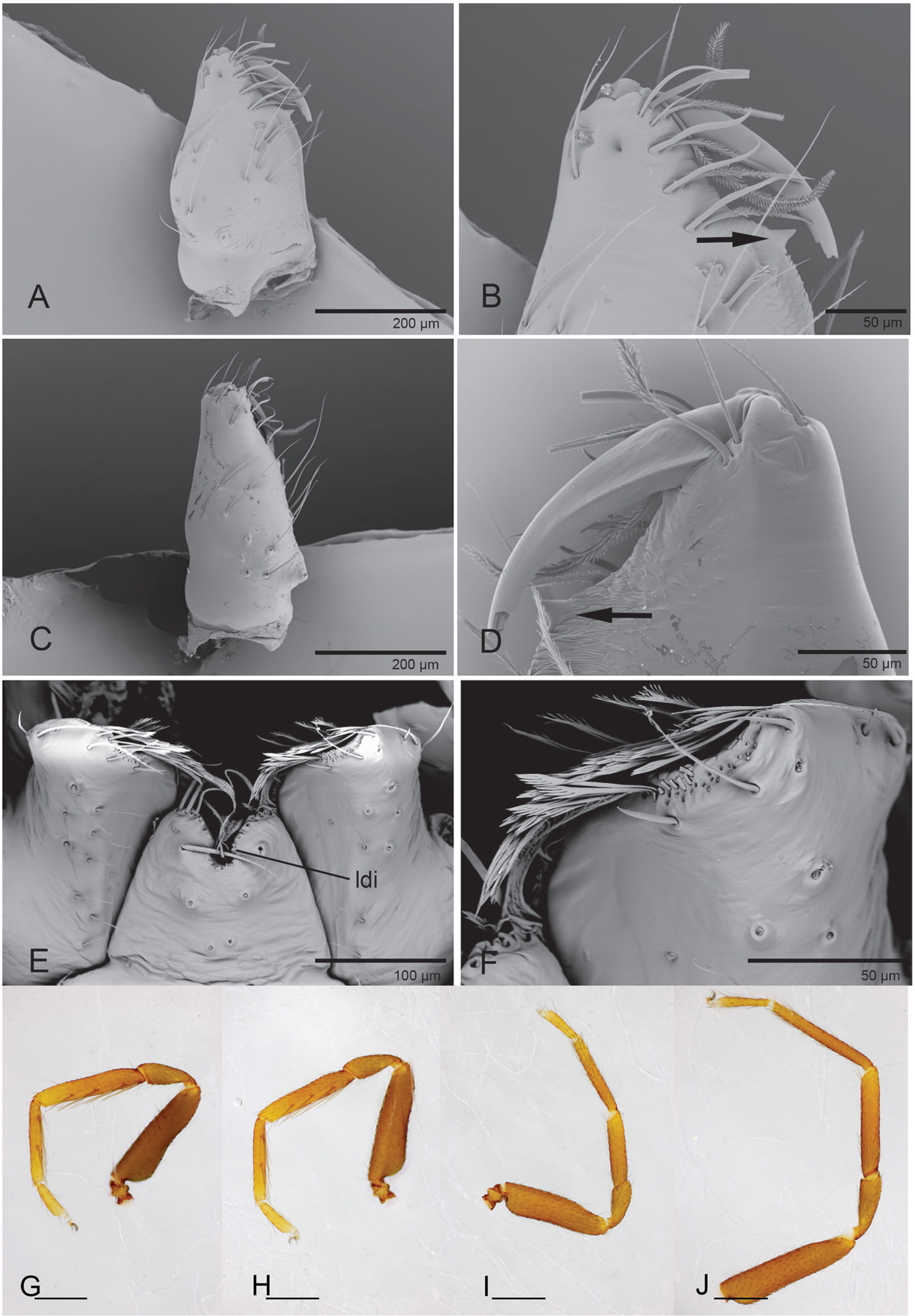

Figure 7. *Promolotra hponkanrazi* sp. nov., male **A–F** SEM **A, C** left chelicera, anterior and lateral views **B, D** left chelicera, anterior and posterior magnified views (arrows show the large denticle) **E** labium and endites, ventral view **F** endite, ventral view **G–J** right legs I–IV, prolateral view. Abbreviation: ldi = labium deep incision. Scale bars: 0.4 mm (**G–J**).

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References

Baehr BC, Harvey MS, Burger M, Thoma M (2012) The new Australasian goblin spider genus *Prethopalpus* (Araneae, Oonopidae). Bulletin of the American Museum of Natural History 369: 1–113. https://doi.org/10.1206/763.1

Jocqué R, Dippenaar-Schoeman AS (2006) Spider Families of the World. Musée Royal de l'Afrique Central, Tervuren, 336 pp.

Li S (2020) Spider taxonomy for an advanced China. Zoological Systematics 45(2): 73–77. https://doi.org/10.11865/zs.202011

Ott R, von Beeren C, Hashim R, Witte V, Harvey MS (2015) *Sicariomorpha*, a new myrmecophilous goblin spider genus (Araneae, Oonopidae) associated with Asian army ants. American Museum Novitates 3843: 1–14. https://doi.org/10.1206/3843.1

Platnick NI, Dupérré N (2012) The goblin spider genus *Costarina* (Araneae, Oonopidae), Part 1. American Museum Novitates 3730: 1–64. https://doi.org/10.1206/3730.2

Thoma M, Kranz-Baltensperger Y, Kropf C, Graber W, Nentwig W, Frick H (2014) The new Southeast Asian goblin spider genus *Aposphragisma* (Araneae, Oonopidae): diversity and phylogeny. Zootaxa 3798: 1–86. https://doi.org/10.11646/zootaxa.3798.1.1

Tong Y, Li S (2013) A new genus and species of oonopid spiders from Laos (Araneae, Oonopidae). Acta Zootaxonomica Sinica 38: 784–789.

Tong Y, Chen H, Liu S, Li S (2018) A new genus of oonopid spiders from Myanmar (Araneae, Oonopidae). ZooKeys 794: 31–43. https://doi.org/10.3897/zookeys.794.29156

Tong Y, Chen Z, Li S (2020) Two new species of the genus *Opopaea* (Araneae, Oonopidae) from Myanmar. ZooKeys 917: 51–61. https://doi.org/10.3897/zookeys.917.48924

Ubick D, Dupérré N (2017) Oonopidae. In: Ubick D, Paquin P, Cushing P, Roth V (Eds) Spiders of North America: an Identification Manual, 2nd Ed. American Arachnological Society, 181–182.

Ubick D, Griswold CE (2011) The Malagasy goblin spiders of the new genus *Molotra* (Araneae, Oonopidae). American Museum Novitates 3729: 1–69. https://doi.org/10.1206/3729.2

WSC (2020) World Spider Catalog. Version 21.0 Natural History Museum Bern. World Spider Catalog. [accessed on 2020.3.7]

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RESEARCH ARTICLE

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Lithobius (*Ezembius*) *varioporus*, a new species from eastern China (Lithobiomorpha, Lithobiidae)

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Abstract

Lithobius (*Ezembius*) *varioporus* **sp. nov.** (Lithobiomorpha, Lithobiidae), recently discovered from Longquanguan Town, Fuping County, Baoding City, Hebei Province, China, is described. Morphologically it resembles to *Lithobius* (*Ezembius*) *laevidentata* Pei, Ma, Hou, Zhu & Gai, 2015 from the Xinjiang Autonomous Region, but can be easily distinguished from the latter by the Tömösváry's organ, slightly smaller than the adjoining ocelli, no secondary sexual modifications on male tibia 14 and 15, posterior accessory spine of legs 14 and 15 present and the number of coxal pores varying considerably from three to eight. The main morphological characters of the known Chinese species of the subgenus *Ezembius* Chamberlin, 1919 based on adult specimens are presented.

Keywords

Centipede, Chilopoda, 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 approximately 60 species and subspecies mostly known from Asia, with little extension into northwestern North America. Known species colonise a wide range of habitats, from the Arctic and sub-Arctic regions to tropical and sub-tropical forests, from steppe and overgrazed stony areas of central Asia to Himalayan montane forests, from the seashore up to 5500 m (Himalayas) (Zapparoli and Edgecombe 2011, Qiao et al. 2018). Although the subgenus was formally proposed as new (Chamberlin 1923), according to Jeekel (2005) its name was validated in 1919 (Chamberlin 1919). *Ezembius* is characterised 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. 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 88 species and subspecies known from the country. Altogether, 25 species of *Ezembius* have been recorded from China, but only one of them has been reported from Hebei Province (Pei et al. 2019, Qiao et al. 2019a, b). Herein, a new species recently discovered in the Hebei Province, China, is described and illustrated. Tables of the main morphological characters of Chinese *Ezembius* species are also presented.

Materials and methods

All specimens were hand-collected under leaf litter or stones. The material was examined with the aid of a Nikon SMZ–1500 stereo microscope equipped with a drawing attachment. 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	anterior dorsal spur 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*) *varioporus*, sp. nov.**

http://zoobank.org/DF87F26E-CDB7-44AE-AF12-654038A0CB93
Figures 1–7, Tables 1, 2

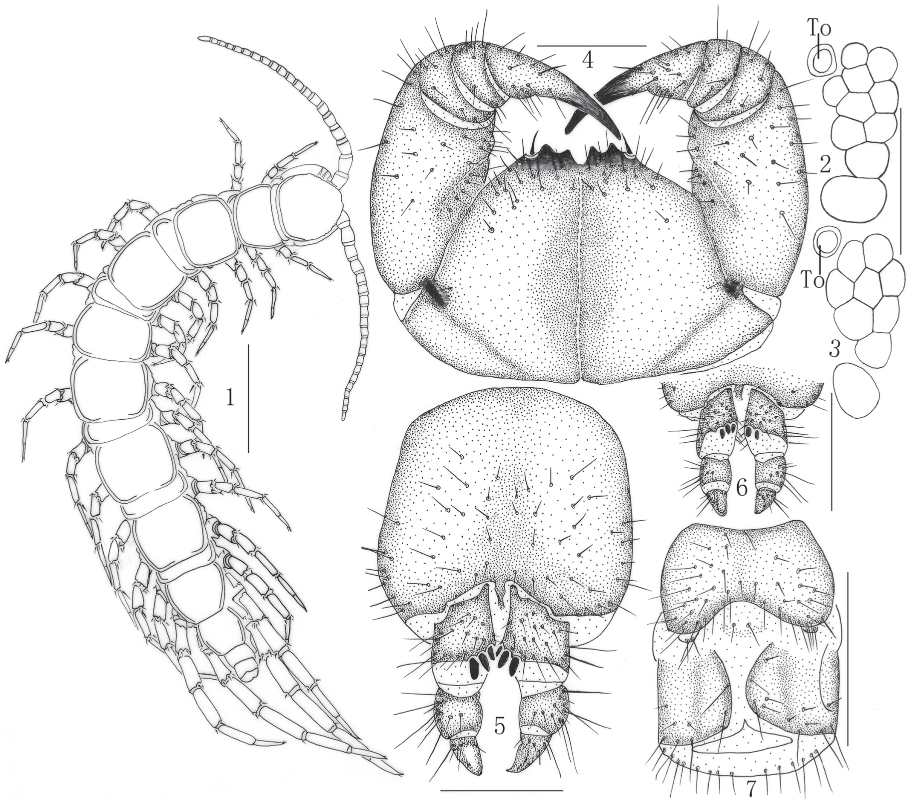
Diagnosis. Body length 12.4–19.1 mm, antennae composed of 20–22 articles, commonly 20 articles, 9–10 ocelli on each side of the head, arranged in three irregular rows, posterior two comparatively large ocelli; Tömösváry's organ larger than the adjacent ocelli; commonly 2+2 forcipular coxosternal teeth, porodonts moderately slender, posterolateral to the lateral-most tooth, posterior angles of all tergites without triangular projections; 3–8 coxal pores, arranged in one row; female gonopods with 3+3 (few 3+2) moderately small coniform spurs, apical claw simple; male gonopods short and small, with three or four long setae on the terminal segment.

Material examined. ***Holotype*:** ♂ (Fig. 1) (EV1). Body length 19.1 mm, cephalic plate 1.8 mm long, 1.7 mm wide, Heiyagou Village, Longquanguan Town, Fuping County, Baoding City, Hebei Province, China, 38°57'03.77"N, 113°48'40.70"E, 1100 m, under litter of the forest floor in a mixed coniferous broad-leaved forest, 5 August 2014, leg. S. Pei, H. Ma. ***Paratypes*** [13♀♀, 19 ♂♂] (EV1): same data as holotype. ***Other material*:** 26 ♀♀, 32 ♂♂ (EV2) Liaodaobei, Longquanguan Town, Fuping County, Baoding City, Hebei Province, China, 38°50'50.12"N, 113°49'50.33"E, 1800 m, 5 August 2014, leg. S. Pei, H. Ma. 20♀♀, 21♂♂ (EV3) Wuyuezhai Mountain, Lingshou County, Shijiazhuang City, Hebei Province, China, 38°43'15.02"N, 114°08'32.62"E, 500 m, under litter of the forest floor in a mixed coniferous broad-leaved forest, 28 Sept 2014, leg. S. Pei, H. Ma.

Description. Body length: 12.4–19.1 mm, cephalic plate 1.4–2.0 mm long, 1.4–1.8 mm wide.

***Colour*:** antennal articles yellow-brown with blackish hue, the black gradually becomes lighter at the end of articles 6 and 7, distal-most article yellow-brown; and all tergites yellow-brown, TT 1, 3, 14, and 15 darker, pleural region pale grey with lavender hue, and sternites pale yellow-brown; basal and proximal parts of forcipules, forcipular coxosternite, SS 14 and 15 darker yellow-brown; all legs yellow-brown, distal tarsi darker.

***Antennae*:** 20–22 articles, commonly 20+20 articles (Fig. 1), few specimens 20+21 or 20+22 articles; antennae article lengths are longer than wide except basal articles, which are equal to widths, distal-most article 2.9–3.2 times as long as wide; abundant setae on the antennal surface, less so on the basal articles, gradual increase in density of setae to ca. the fifth article, then more or less constant.



Figures 1–7. *Lithobius* (*Ezembius*) *varioporus* sp. nov., **1–2, 4, 7** holotype, male **1** habitus, dorsal view **2, 3** ocelli and Tömösváry's organ **(To)**, lateral view **4** forcipulae, ventral view **5, 6** paratype, female **5** posterior segments and gonopods, ventral view **6** gonopods, ventral view **7** posterior segments and gonopods, ventral view. Scale bars: 2 mm (**1**); 250 μm (**2, 3**); 500 μm (**4–7**).

Cephalic plate smooth, convex, slightly longer than wide; tiny setae emerging from setal sockets 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, the middle of the posterior edge is very slightly concaved forward (Fig. 1). Nine to ten approximate oval ocelli on each side (Figs 2, 3), domed, translucent, usually darkly pigmented, situated in three irregular rows; the posterior two ocelli comparatively large; others subequal in size. Tömösváry's organ situated at anterolateral margin of the cephalic plate, slightly smaller than the adjoining ocelli and lying well apart from them (Figs 2, 3).

Coxosternite subtrapezoidal (Fig. 1), anterior margin narrow, lateral margins slightly longer than medial margins; median diastema moderately deep, narrow U-shaped; anterior margin with 2+2 blunt triangular teeth; porodonts slender, lying posterolateral to and separated from the lateral-most tooth (Fig. 4); scattered long setae on the ventral side of coxosternite, longer setae near the dental margin.

Table 1. Leg plectrotaxy of *Lithobius* (*Ezembius*) *varioporus* sp. nov. (based on 59 females).

Legs	Ventral					Dorsal				
	C	Tr	P	F	Ti	C	Tr	P	F	Ti
1			mp	amp	am			mp	ap	ap
2			mp	am	am			amp	ap	ap
3–10			mp	amp	am			amp	ap	ap
11			amp	amp	am			amp	ap	ap
12		m	amp	amp	am			amp	ap	ap
13		m	amp	amp	am		a	amp	p	ap
14		m	amp	amp	am		a	amp	p	p
15		m	amp	amp	a		a	amp	p	

Table 2. Leg plectrotaxy of *Lithobius* (*Ezembius*) *varioporus* sp. nov. (based on 73 males).

Legs	Ventral					Dorsal				
	C	Tr	P	F	Ti	C	Tr	P	F	Ti
1			mp	amp	am			mp	ap	a
2–11			mp	amp	am			amp	ap	ap
12			amp	amp	am		a	amp	ap	ap
13		m	amp	amp	am		a	amp	p	ap
14		m	amp	amp	am		a	amp	p	p
15		m	amp	am(p)	a		a	amp	p	

Letters in brackets indicate variable spines (absent in 5 specimens).

All ***tergites*** smooth, without wrinkles, dorsum slightly convex; tiny setae emerging from setal sockets scattered sparsely over the entire surface, few long setae near the margin. Lateral marginal ridges of all tergites continuous. Posterior margin of TT 1, 3, and 5 feebly concave, posterior marginal ridges continuous, posterior margins of TT 7, 8, 10, 12, and 14 feebly concave, posterior marginal ridges discontinuous. Posterior angles of tergites generally rounded, without triangular projections. Miniscule setae scattered sparsely over the surface, two or three slightly thick and long setae on anterior and posterior angles of each tergite.

Sternites. Posterior side narrower than anterior side, generally inverted trapezoidal, smooth; setae emerging from setal sockets sparsely scattered on the surface and lateral margin, 3–5 long setae on the surface of the anterior part of each sternite, two or three comparatively long setae scattered sparsely on the surface of the posterior part of each sternite.

Legs robust, tarsal articulation ill-defined on legs 1–13, faint trace on ventral side, well-defined on legs 14 and 15; short to long setae sparsely scattered over the surface of prefemur, femur, tibia, and tarsus of all legs, with more setae on the tarsal surface; setae on dorsal and ventral surface of tarsus slightly longer than the anterior and posterior, 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. All legs with fairly long curved claws; legs 1–13 with anterior and posterior accessory spines; anterior accessory spines moderately long and slender, forming a moderately small angle with the claw, posterior accessory spines slightly more robust, forming a comparatively large angle with the claw, legs 14 and 15 only with small posterior accessory spines; legs 14 and 15 moderately thicker and longer than the anterior pairs in the female; In the female, tarsus 1 4.0–6.0 times as long as wide in legs 15, tarsus 2 ca. 73.1 %–77.3 % length of tarsus on legs 15; In the male, tarsus 1 3.3–7.3 times as long as wide in legs 15, tarsus 2 ca. 51.1 %–77.6 % length of tarsus on legs 15. Leg plectrotaxy provided in Table 1.

Coxal pores 3–8, round to slightly oval, in a row; in the female, 4554, 67(8)7(8)6, 5(6)765, 6(7)776, 66(7)65, in the male, 66(7)7(6)5(4), 565(6)3, coxal pore field set in a relatively shallow groove, the coxal pore-field fringe with a prominence; prominence with 10–15 short to moderately long setae sparsely scattered over the surface.

Female S 15 anterior margin broader than posterior, generally inverted trapezoidal, posteriomedially straight, colour usually yellow-brown; short to long sparse setae evenly scattered on surface; surface of the lateral sternal margin of genital segment well chitinised, posterior margin of genital sternite deeply concave between condyles of gonopods, except for a small, median approximately rhombic-shaped bulge; relatively long setae sparsely scattered over ventral surface of the genital segment. Gonopods (Figs 5, 6): first article fairly broad, bearing 22–26 moderately long setae, arranged in five irregular rows; generally with 3+3 (3+2 in only two specimens) moderately long and slender, coniform spurs, inner spur slightly smaller than the outer, dorsolateral setae absent; second article with 12–16 long setae, arranged in three irregular rows, 9–12 stout setae on the dorsal side; third article with five or six comparatively long setae, arranged in two irregular rows, four or five stout setae on the dorsal side; third article with a simple broad apical claw (Figs 5, 6).

Male S 15 posterior margin narrower than anterior, posteriomedially straight, sparsely covered with long setae on the surface; sternite of genital segment smaller than in female, usually well sclerotised, posterior margin deeply concave between the gonopods, without median bulge; long setae sparsely scattered on the ventral surface of the genital segment, fringed with longer setae along the posterior margin; gonopods short, appearing as a small hemispherical bulge, with three or four long setae, apically slightly sclerotised (Fig. 7).

Habitat. The specimens studied here were collected from a mixed coniferous broad-leaved forest at ca. 500–1800 m above sea level, in moderately moist habitats under roadside stones and litter of the forest floor.

Etymology. The specific epithet *varioporus* refers to the coxal pore numbers varying considerably from three to eight.

Discussion. The new species is morphologically close to *L.* (*E.*) *laevidentata* Pei, Ma, Hou, Zhu & Gai, 2015 and to *L.* (*E.*) *tetraspinus* Pei, Lu, Liu, Hou & Ma, 2018, both from the Xinjiang Uygur Autonomous Region, China, with which it shares 20–22 antennal articles, 9–10 ocelli arranged in three irregular rows, the posterior two ocelli comparatively large, 3+3 spurs on female gonopods, no anterior accessory spines on legs 15.

However, the new species can be easily distinguished from *L.* (*E.*) *laevidentata* by the size of the Tömösváry's organ, slightly smaller than the adjoining ocelli, rather than subequal to the largest ocellus as in *L.* (*E.*) *laevidentata*. The new species has no secondary sexual modifications on the male 15 tibia compared to *L.* (*E.*) *laevidentata*, in which a distinct and shallow dorsal furrow is present on the same leg; moreover, in the new species legs 14 and 15 bears a small accessory spines only on the posterior side vs. both anterior and posterior accessory spines are present on legs 14, and only with posterior accessory spines present on legs 15 in *L.* (*E.*) *laevidentata*.

The new species can be easily distinguished from *L.* (*E.*) *tetraspinus* by the Tömösváry's organ, slightly smaller than the adjoining ocelli in contrast to subequal in size to adjoining ocelli in *L.* (*E.*) *tetraspinus*. Moreover, the new species has no secondary sexual modifications on the leg 15 male tibia vs. the dorsal sulci on the femur in *L.* (*E.*) *tetraspinus*. In the new species, legs 14 and 15 bear small accessory spines only in the posterior side instead of both anterior and posterior accessory spines present on legs 14, and lacking accessory spines on legs 15 in *L.* (*E.*) *tetraspinus*. The new species must be also easily distinguished from the other *Lithobius* (*Ezembius*) species to date known from China by the coxal pore number, varying considerably from three to eight, not only among specimens, but also in the same individual.

To assist in the identification of the *Lithobius* species of the subgenus *Ezembius* from China, the main morphological characters based on adult specimens are presented in Table 3.

Table 3. Range and main morphological characters of the known Chinese species of subgenus *Lithobius* (*Ezembius*) Chamberlin, 1919.

Characters	*L. anabilineatus*	*L. anasulcifemoralis*	*L. bidens*	*L. bilineatus*	*L. chekianus*	*L. datongensis*
Authorities	Ma et al. 2015	Ma et al. 2013	Takakuwa 1939	Pei et al. 2014	Chamberlin and Wang 1952	Qiao et al. 2018
Distribution	China S (Guangxi)	China S (Guangxi)	China S (Taiwan)	China S (Guangxi)	China S (Zhengjiang and Taiwan)	China NW (Qinghai Province)
Body length (mm)	11.9–12.1	10.1–12.3	15.0	9.0–9.1	16.0	12.3–14.2
Number of antennal articles	23+23 articles in female, unkown 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
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
Posterior ocellus	round, large	oval to round, large	comparatively large	oval to rounded	oval to round, comparatively large	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
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
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
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 porodonts separated from lateral tooth laterally

Characters	***L. anabilineatus***	***L. anasulcifemoralis***	***L. bidens***	***L. bilineatus***	***L. chekianus***	***L. datongensis***
Tergites	smooth, backside slightly hunched	smooth	not reported	smooth, slightly hunched behind	not reported	almost 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
Shape of coxal pores	round or slightly ovate	round or slightly ovate	round	ovate	not reported	rounded
Tarsus 1–tarsus 2 articulation on legs 1–13	not well-defined	not well-defined	Well-defined	not well-defined	not reported	distinct
Male 14th legs	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
Male 15th legs	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
Dorsal sulci on male 14th legs	absent	absent	not reported	with two, shallow longitudinal sulci	not reported	not reported
Dorsal sulci on male 15th 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
DaC spure	on 14th–15th legs	on 14th–15th legs	absent	on 4th–15th legs	on 14th–15th legs	on 12th–15th
14th accessory spine	anterior accessory spine reduced in size, only half length of posterior accessory spine	absent	not reported	anterior accessory spine absent	present	present
15th accessory spine	absent	absent	not reported	anterior accessory spine absent	present	anterior accessory spine absent
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	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
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
Apical claw of female gonopods (and lateral denticles)	simple, small subtriangular teeth in the inner	apical claw dimidiate	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
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

Characters	***L. dulanensis***	***L. gantoensis***	***L. giganteus***	***L. insolitus***	***L. irregularis***	***L. laevidentata***
Authorities	Qiao et al. 2019	Takakuwa and Takashima 1949	Eason 1986	Eason 1993	Takakuwa and Takashima 1949	Pei et al. 2015
Distribution	China NW (Qinghai Province)	China NW (Shanxi)	China N (Inner Mongolia Autonomous region)	China S (Hong Kong)	China W (Shanxi)	China NW (Xinjiang Uygur)
Body length (mm)	20.5	9.0	15.0–50.0	10.0–11.5	12.0	9.6–13.3
Number of antennal articles	20–21	20–23	20+20	18+18–19+19	20+20	19+19–21+21 commonly 20+20
Number, arrangement and shape of the ocelli	11–12, in 3 rows	6, in 2 rows	6–10, in 2–3 rows	6–8, in 2 rows	7, in 2 rows	8–10, in 3 rows

Characters	***L. dulanensis***	***L. gantoensis***	***L. giganteus***	***L. insolitus***	***L. irregularis***	***L. laevidentata***
Posterior ocellus	oval to rounded, comparatively large	oval to round, comparatively large	oval to round, comparatively large	oval to round, comparatively large	round, comparatively large	posterior two ocelli bigger than seriate ocelli
Seriate ocelli	the second row smaller than the first, the third smallest	comparatively large	not reported	not reported	subequal	other seriate ocelli slightly larger than ocelli adjoining ventrally
Tömösváry's organ	Slightly smaller than the adjoining ocelli	subequal in size to adjoining medium large ocelli	slightly smaller than adjoining ocelli	slightly smaller than adjoining ocelli	same size as largest ocellus	subequal in size to adjoining ocelli
Number and arrangement of coxosternal teeth	2+2 moderately robustteeth	2+2, approximately sharp, small	2+2	2+2, approximately sharp, small	2+2, small	2+2, approximately blunt
Porodont	Slender lying posterolateral to the most lateral tooth	not reported	not reported	slender, lying posterolateral to lateral tooth, their base slightly bulged	long, their base slightly bulged	thick and long, lying posterolateral to lateral-most teeth
Tergites	Smooth and all posterior angles rounded without projections	smooth, without wrinkles	smooth, with slightly wrinkles	T1 smooth, other with wrinkles	smooth	smooth, without wrinkles, backside slightly hunched
Number of coxal pores	5667 or 5666	3333	3333, 4554, 4555, 4565, 5565 or 5566	3–6, male 3443; female 4454, 4555, 5555, 5565	3–10, female 3–6 in 12th leg, 4–6 in 13th leg, 7–10 in 14th and 15th leg	2–5, female commonly 4555, 4554, sometime 3454, 3455, 3343. male commonly 2332, 2333, sometime 3444, 3333
Shape of coxal pores	Circularor slightly ovate	round	round	round	round	round or slightly ovate
Tarsus 1–tarsus 2 articulation on legs 1–13	fused	not reported	Well-defined	not defined	Well-defined	not well-defined
Male 14th legs	longer and thicker than legs 1–13	not reported	not reported	distinctly thick and strong	not reported	remarkably thicker and stronger
Male 15th legs	longer and thicker than legs 1–13	not reported	not reported	distinctly thick and strong, with dark zones on dorsal of tibia	not reported	markedly thicker and stronger
Dorsal sulci on male 14th legs	absent	not reported	not reported	absent	not reported	absent
Dorsal sulci on male 15th legs	absent	not reported	not reported	absent	not reported	with a distinct, shallow, dorsal sulci on the tibia
DaC spure	on 11th–15th	absent	on 12th–15th legs (on 11th and 12th legs sometimes present)	absent	on 13th–15th legs	on 12th–15th legs
14th accessory spine	anterior accessory spines absent	present	present	not reported	not reported	present
15th accessory spine	absent	present	absent	absent	not reported	anterior accessory spines absent
Number and shape of spurs on female gonopods	2+2 moderately small coniform spurs	1+1, conical spurs	2+2	3+3, coniform spurs	2+2 or 2+3, moderately small, blunt, coniform spurs	3+4, or 4+4 small, blunt, coniform spurs, commonly with 3+3, inner spur smaller than outer one
Dorsal side of second article of female gonopods	with six dorsolateral setae	not reported	with eight spines in two irregular rows lying dorsally on its external margin	not reported	not reported	with three long setae lying dorsally on its anterior external margin
Apical claw of female gonopods (and lateral denticles)	unidentate, curved	simple	simple	simple	simple and broad	simple and broad
Male gonopods	small, one-segmented, with two long setae, apically slightly chitinized, flat	not reported	not reported	not reported	not reported	small bulge, with one to two long setae apically slightly sclerotised

Characters	***L. longibasitarsus***	***L. lineatus***	***L. mandschreiensis***	***L. maqinensis***	***L. multispinipes***	***L. parvicornis***
Authorities	Qiao et al. 2018	Takakuwa 1939	Takakuwa 1940	Qiao et al. 2019b	Pei et al. 2016	Zapparoli 1991
Distribution	China NW (Qinghai)	China S (Taiwan)	China (Taiwan, Sichuan, Jiangsu, Heilongjiang, Jilin, Liaoning)	China NW (Qinghai)	China NW (Xinjiang Uygur)	China S (Taiwan)

Characters	*L. longibasitarsus*	*L. lineatus*	*L. mandschreiensis*	*L. maqinensis*	*L. multispinipes*	*L. parvicornis*
Body length (mm)	17.0–18.0	18.0	22.0–23.0	13.10–14.60	11.6–22.6	16.0
Number of antennal articles	20+20	19+19–21+21	20–28	20+20	commonly 20+20, (three specimens with 20+21, one specimen with 20+26 of 134 specimens)	20+20, 21+21
Number, arrangement and shape of the ocelli	11, in 3 rows	8–11, in 3 rows	9–13, in 3 rows	9–10, in 3 rows	8, in 3 rows	3–4, in 1 or 2 rows
Posterior ocellus	posterior ocellus largest	comparatively small	comparatively large	the most posterior ocellus largest	two ocelli large, oval to rounded	comparatively large
Seriate ocelli	not reported	not reported	same size	the ocelli of the bottom row small	two near ventral margin moderately small, others almost equal	not reported
Tömösváry's organ	smaller than adjacent ocelli	same size as adjoining ocelli	larger than adjoining ocelli	almost the same size as adjacent ocelli	slightly smaller than adjoining ocelli	not reported
Number and arrangement of coxosternal teeth	3+2 blunt nipple-like teeth	2+2, comparatively large	2+2, small and sharp	2 + 2	3+3, slightly triangular	2+2
Porodont	thick and strong separated from lateral tooth ventrolaterally	long and strong	lying posterolateral to lateral-most tooth	setiform porodonts on small knobs	thick and long, lying posterolateral to lateral-most tooth	lying posterolateral to the lateral-most teeth
Tergites	all smooth, without wrinkles	smooth	smooth, without wrinkles	smooth, never rugose	smooth, without wrinkles and slightly hunched behind	smooth
Number of coxal pores	6555	6–7, usually 66(7)6	776(7)5(6)	6666	3–5, 4555, 5555, 4444, 4455 (females) and 4444, 3344 (males)	3334
Shape of coxal pores	circular	round to ovate	round or ovate	round and uniseriate, the most proximal pore on 15th coxae minute	round to ovate	not reported
Tarsus 1–tarsus 2 articulation on legs 1–13	well-defined	well-defined	well-defined	unipartite tarsi	well-defined	not reported
Male 14th leg	moderately thicker and longer	not reported	not reported	longer and thicker than 1–13	thick and strong	not reported
Male 15th leg	moderately thicker and longer	not reported	not reported	longer and thicker than 1–13	thick and strong	not reported
Dorsal sulci on male 14th legs	absent	absent	not reported	not reported	absent	not reported
Dorsal sulci on male 15th legs	absent	not reported	not reported	not reported	absent	not reported
DaC spure	on 13th–15th legs, 12th sometimes present	on 14th–15th legs	on 12th–15th legs	on 12th–15th legs, 11th sometimes present	on 11th–15th legs, 9th–10th sometimes present	not reported
14th accessory spine	present	present	not reported	posterior accessory spurs present	present	not reported
15th accessory spine	absent	present	not reported	absent	absent	not reported
Characters	***L. longibasitarsus***	***L. lineatus***	***L. mandschreiensis***	***L. maqinensis***	***L. multispinipes***	***L. parvicornis***
Number and shape of spurs on female gonopods	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 moderately small, coniform spurs, inner spur smaller	2+2, blunt, coniform spurs, with inner spur smaller than outer one	2+2

Characters	***L. longibasitarsus***	***L. lineatus***	***L. mandschreiensis***	***L. maqinensis***	***L. multispinipes***	***L. parvicornis***
Dorsal side of second article of female gonopods	three long setae along dorsolateral ridge	not reported	not reported	not reported	with 3–4 long setae and 5–6 spines lying dorsally on its external margin	not reported
Apical claw of female gonopods (and lateral denticles)	simple, having small triangular protuberance on ventral side	simple	simple	unidentate, curved with a small triangular protuberance on ventral side	simple	simple
Male gonopods	small, semicircular article with 3-5 seta on its surface	hemispherical bulge,	without setae	small, undivided, oblique apically, with 2 setae	hemispherical bulge, having a long seta, and apically slightly sclerotised	not reported

Characters	***L. polyommatus***	***L. rhysus***	***L. sulcipes***	***L. sulcifemoralis***	***L. tetraspinus***	***L. varioporus***	***L. zhui***
Authorities	Qiao et al. 2019	Attems 1934	Attems 1927	Takakuwa and Takashima 1949	Pei et al. 2018	This paper	Pei et al. 2011
Distribution	China NW (Tibet)	China S (Fujian and Taiwan)	China S (Taiwan)	China W (Shanxi)	China NW (Xinjiang Uygur)	China E (Hebei)	China NW (Xinjiang Uygur)
Body length (mm)	16.10 –18.30	15.0	Not reported	12.0	9.6–13.3	12.4–19.1	8.1–15.0
Number of antennal articles	20+20	20+20 in female, 20+21 in male	19–22	20+20	19–22, commonly 20	20–22	20–24, commonly 20
Number, arrangement and shape of the ocelli	14, in 3 rows	8, in 4 rows	7, in 2 rows	6	8–10, in 3 rows	9–10, in 3 rows	10–13, in 3–4 rows
Posterior ocellus	posterior ocellus comparatively large	comparatively large	comparatively large	all ocelli same size	two ocelli comparatively large	posterior two ocelli comparatively large	comparatively large
Seriate ocelli	almost equal	not reported	not reported	same size	the adjoining Tömösváry organ slightly small	others subequal in size	dorsal ones moderately large, those near ventral margin of ocellar field moderately small, others of moderate size
Tömösváry's organ	moderately smaller than the adjoining ocelli	not reported	not reported	same size as ocelli	subequal in size to adjoining ocelli	slightly smaller than the adjacent ocelli	slightly larger than adjoining ocelli
Number and arrangement of coxosternal teeth	2 + 2 subtriangular slightly acute teeth	2+2	2+2	2+2, small and sharp	2+2 subtriangular slightly acute	2+2 blunt triangular teeth	2+2 moderately small and pointed
Porodont	thick and strong, just posterolateral and separated from the lateral tooth	not obvious	not reported	slender and long	thick and strong, just posterolateral and separated from lateral tooth	slender, lying posterolateral to and separated from the lateral-most tooth	moderately thick in basal, moderately pointed, just posterolateral to lateral tooth
Tergites	smooth without wrinkles	with shallow wrinkles	Smooth, posterior angles slightly triangular in T14	not reported	smooth, without wrinkles, dorsum slightly convex	smooth, without wrinkles, dorsum slightly convex	smooth, without wrinkles, backside slightly hunched
Number of coxal pores	4–7, 5676, 5666 (females) 5565, 4554 (males)	6554	4554	5555	usually 4555, 4554, rarely 3454, 3455, 3343 in females and usually 2332, 2333, rarely 3444, 3333 in males	in the female, 4554, 67(8)7(8)6, 5(6)765, 6(7)776, 66(7)65, in the male, 66(7)7(6)5(4), 565(6)3	2–4, 3444, 3344, 3443, 3333 in female, and 3443, 2343, 2433, 2333 in male.
Shape of coxal pores	round or slightly oval	round	round	round	round or slightly oval	round to slightly oval	round or slightly ovate
Tarsus 1–tarsus 2 articulation on legs 1–13	ill-defined	not reported	well-defined	well-defined	ill–defined	well-defined	well–defined
Male 14th legs	slightly thicker in the female, significantly thicker and stronger in the male	not reported	not reported	thick and strong	significantly thicker and stronger	moderately thicker and longer	moderately thicker and stronger

Characters	*L. polyommatus*	*L. rhysus*	*L. sulcipes*	*L. sulcifemoralis*	*L. tetraspinus*	*L. varioporus*	*L. zhui*
Male 15th legs	slightly thicker in the female, significantly thicker and stronger in the male	femur and tibia thicker	femur and tibia thicker	thick and strong	significantly thicker and stronger	moderately thicker and longer	thicker and stronger, with a circular protuberance on distal end of tibia
Dorsal sulci on male 14th legs	with a longitudinal discontinuous shallow and narrow groove on dorsal side of tibia, and a faintly black vertical line at the bottom on dorsal side	not reported	present on femur	present on femur and tibia	absent	absent	absent
Dorsal sulci on male 15th legs	with a longitudinal discontinuous shallow and narrow groove on dorsal side of tibia, and a faintly black vertical line at the bottom on dorsal side	not reported	present on femur and tibia	present on femur and tibia	present on femur	absent	absent
DaC spure	on 11th–15th legs	on 15th legs present	on 15th legs present	absent	on 12th–15th legs	on 12th–15th legs	on 13th–15th legs, 12th sometimes present
14th accessory spine	present	not reported	not reported	not reported	present	anterior accessory spine absent	present
15th accessory spine	absent	absent	not reported	not reported	absent	anterior accessory spine absent	absent
Number and shape of spurs on female gonopods	2 + 2 moderately long and slender, bullet-shape spurs	2+2, slender	2+2, thick spurs	2+2, strong, long and sharp	3+3, few 3+4, only one 4+4 coniform spurs	3+3 (seldom 3+2) moderately long and slender, coniform	2+2 moderately long, coniform spurs, inner spur slightly smaller and more anterior than outer
Dorsal side of second article of female gonopods	9 long setae lying dorsally on the posterior part of the external margin	not reported	not reported	not reported	3 long setae and four short, robust spines lying dorsally on posterior part of external margin	no setae and spines	three spurs arranged in one irregular row on dorsal terminal part
Apical claw of female gonopods (and lateral denticles)	simple	simple	dimidiate	simple	simple, with a very small subtriangular blunt denticle on inner margin	simple	broad, and tridentate
Male gonopods	short, apically slightly sclerotized, appearing as a small hemispherical bulge with 2 long setae	not reported	not reported	not reported	small hemispherical bulge, with 1–2 long setae	short, small hemispherical bulge, with 1–3 long setae, apically slightly sclerotized	small bulge, with 1–2 long setae on surface, and terminal slightly sclerotised

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References

Attems C (1927) Neue Chilopoden. Zoologischer Anzeiger 72: 291–305.

Attems C (1934) Einige neue Geophiliden und Lithobiiden des Hamburger Museums. Zoologischer Anzeiger 107: 310–317.

Bonato L, Edgecombe GD, Lewis JGE, Minelli A, Pereira LA, Shelley RM, Zapparoli M (2010) A common terminology for the external anatomy of centipedes (Chilopoda). ZooKeys 69: 17–51. https://doi.org/10.3897/zookeys.69.737

Chamberlin RV (1913) The lithobiid genera *Nampabius*, *Garibius*, *Tidabius* and *Sigibius*. Bulletin of the Museum of Comparative Zoology, Harvard College 57: 37–104.

Chamberlin RV (1919) The Chilopoda collected by the Canadian Arctic Expedition, 1913–1918. In: Report of the Canadian Arctic Expedition, 1913–1918. Volume III: Insects. Part H: Spiders, Mites and Myriapods, 15–22.

Chamberlin RV (1923) Chilopods of the Pribilof Islands. North American Fauna 46: 240–244.

Chamberlin RV, Wang YX (1952) Some records and descriptions of Chilopods from Japan and other oriental areas. Proceeding of the Biological Society of Washington 65: 177–188.

Chao J, Lee K, Chang H (2018) *Lithobius* (*Monotarsobius*) *meifengensis*, a new species of centipede from high altitude forest in central Taiwan (Chilopoda, Lithobiomorpha, Lithobiidae). ZooKeys 741: 181–192. https://doi.org/10.3897/zookeys.741.21036

Eason EH (1983) The identity of the European and Mediterranean species of Lithobiidae (Chilopoda) described by KW Verhoeff and now represented by material preserved in the British Museum (Natural History). Zoological Journal of the Linnean Society of London 77: 111–144. https://doi.org/10.1111/j.1096-3642.1983.tb00526.x

Eason EH (1986) On the synonymy of *Lithobius giganteus* Sseliwanoff, 1881 and the taxonomic status of *Porobius* Attems, 1926 (Chilopoda). Annalen des Naturhistorischen Museums, Wien 87B: 181–192.

Eason EH (1993) Descriptions of four new species of *Lithobius* from the oriental region and a redescription of *Australobius palnis* (Eason 1973) from Sri Lanka (Chilopoda: Lithobiomorpha). Bollettino del Museo Civico di Storia Naturale di Verona 17: 181–199.

Jeekel CAW (2005) Nomenclator generum et familiarum Chilopodorum: a list of the genus and family-group names in the class Chilopoda from the 10th edition of Linnaeus, 1758, to the end of 1957. Myriapod Memoranda Supplement 1: 1–130.

Ma HQ, Pei SJ, Hou XJ, Zhu TG, Gai YH (2015) *Lithobius* (*Ezembius*) *anabilineatus* sp. nov., a new species (Lithobiomorpha: Lithobiidae) from Eastern China. Oriental Insects 49(3–4): 256–263. https://doi.org/10.1080/00305316.2015.1081647

Ma HQ, Pei SJ, Hou XJ, Zhu TG, Wu DY, Gai YH (2014) An annotated checklist of Lithobiomorpha of China. Zootaxa 3847(3): 333–358. https://doi.org/10.11646/zootaxa.3847.3.2

Ma HQ, Pei SJ, Wu DY, Gai YH (2013) A new lithobiid centipede of *Lithobius* (*Ezembius*) (Lithobiomorpha) from China. Oriental Insects 47(1): 1–6. https://doi.org/10.1080/00305316.2012.753763

Pei SJ, Liu HP, Lu YM, Hou XJ, Ma HQ (2019) *Lithobius* (*Ezembius*) *ternidentatus* sp. n. (Lithobiomorpha, Lithobiidae), a new species from China. ZooKeys 829: 1–13. https://doi.org/10.3897/zookeys.829.30884

Pei SJ, Lu YM, Liu HP, Hou XJ, Ma HQ (2018) *Lithobius* (*Ezembius*) *tetraspinus*, a new species of centipede from northwest China (Lithobiomorpha, Lithobiidae). ZooKeys 741: 203–217. https://doi.org/10.3897/zookeys.741.19980

Pei SJ, Lu YM, Liu HP, Hou XJ, Ma HQ, Zapparoli M (2016) *Lithobius* (*Ezembius*) *multispinipes* n. sp. a new species of centipede from North West China (Lithobiomorpha: Lithobiidae). Zootaxa 4169(2): 390–400. https://doi.org/10.11646/zootaxa.4169.2.12

Pei SJ, Ma HQ, Hou XJ, Zhu TG, Gai YH (2015) *Lithobius* (*Ezembius*) *laevidentata* sp. n., a new species (Chilopoda: Lithobiomorpha: Lithobiidae) from the Northwest region of China. Biologia 70(8): 1113–1117. https://doi.org/10.1515/biolog-2015-0124

Pei SJ, Ma HQ, Shi BJ, Wu DY, Gai YH (2011) A new centipede species of *Lithobius* Leach (Lithobiomorpha: Lithobiidae) from China, Oriental Insects 1: 108–114. https://doi.org/10.1080/00305316.2011.590642

Pei SJ, Ma HQ, Zhu TG, Gai YH (2014) A new species of *Lithobius* (*Ezembius*) Chamberlin (Lithobiomorpha: Lithobiidae) from China. Oriental Insects 48(1–2): 102–107. https://doi.org/10.1080/00305316.2014.959787

Qiao PH, Ma HQ, Pei SJ, Zhang TZ, Su JP (2019) *Lithobius* (*Ezembius*) *polyommatus* sp. n. and *Lithobius* (*Ezembius*) *dulanensis* sp. n. (Lithobiomorpha: Lithobiidae), two new species from Qinghai-Tibet Plateau, China Biologia 74(5): 455–462. https://doi.org/10.2478/s11756-018-00173-z

Qiao PH, Qin W, Ma HQ, Zhang TZ, Su J, Lin GH (2019) Two new species of lithobiid centipedes and the first record of *Lamyctes africanus* Porath (Chilopoda: Lithobiomorpha) in China. Journal of Natural History 53(15–16): 897–921. https://doi.org/10.1080/00222933.2019.1606355

Qiao PH, Qin W, Ma HQ, Zhang TZ (2018) Two new species of *Lithobius* on Qinghai-Tibetan plateau identified from morphology and COI sequences (Lithobiomorpha: Lithobiidae). ZooKeys 785: 11–28. https://doi.org/10.3897/zookeys.785.28580

Takakuwa Y (1939) The species of genus *Lithobius* from Japan. Transactions of the Sapporo Natural History Society 16: 28–37.

Takakuwa Y (1940) Class Chilopoda, Epimorpha, Lithobiomorpha. In: Fauna Nipponica. Vol. 9, Fas. 8, No. 3. Sanseido Book Store, Tokyo, 104 pp.

Takakuwa Y, Takashima H (1949) Myriapods collected in Shansi, North China. Acta Arachnologica 11: 51–69. https://doi.org/10.2476/asjaa.11.51

Zapparoli M (1991) Note su alcune specie di chilopodi della regione palestinese. Fragmenta Entomologica 23: 15–33.

Zapparoli M, Edgecombe GD (2011) Lithobiomorpha. In: Minelli A (Ed.) Treatise on Zoology-Anatomy, Taxonomy, Biology – The Myriapoda, Volume 1 Jordaan Luchtmans, Brill, Leiden/Boston, 371–389.

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RESEARCH ARTICLE

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Cicinnus chambersi: a new species of sack-bearer moth (Lepidoptera, Mimallonidae, Cicinninae) from southeastern Arizona, USA

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Abstract

A new species of cicinnine Mimallonidae, *Cicinnus chambersi* **sp. nov.**, is described from the Sky Islands Region of southern Arizona, USA. The new species is closely related to *C. mexicana* (Druce), type locality Veracruz, Mexico, based on morphology and genetics. The other *Cicinnus* species known from the United States, the common *C. melsheimeri* (type locality Pennsylvania, USA) is morphologically and genetically distinct from both *C. chambersi* and *C. mexicana*. The new species is compared to *C. mexicana* and *C. melsheimeri*, as well as other Mexican *Cicinnus*. The life history of *C. chambersi* is unknown, but its description should facilitate future studies on this rarely reported North American mimallonid, a species which may have only recently become established in the United States. *Cicinnus chambersi* is the fifth known Mimallonidae species from the United States, and the first described from the country in nearly half a century.

Keywords

Cicinnus chambersi sp. nov., Mimallonoidea, Sky Islands, taxonomy

Introduction

Mimallonidae are a family of approximately 300 species of moths endemic to the New World, with the vast majority of species found in Central and South America (St Laurent and Kawahara 2019). The most recent revision of North American Mimallonidae by Franclemont (1973) recognized four species from the United States: *Lacosoma arizonicum* Dyar, 1898, *L. chiridota* Grote, 1864, *L. elassa* (Franclemont, 1973), and *Cicinnus melsheimeri* (Harris, 1841). Franclemont (1973) treated three genera in North America: *Lacosoma* Grote, 1864, *Naniteta* Franclemont, 1973, and *Cicinnus* Blanchard, 1852. Apart from the synonymization of *Naniteta* with *Lacosoma* by St Laurent et al. (2018), no major taxonomic work has since been carried out focusing on the Mimallonidae of the United States. Recent phylogenetic and systematic research has ultimately led to a major reassessment of the intrafamilial classification of Mimallonidae, resulting in the recognition of various subfamilies and tribes, new genera, and a multitude of new combinations (St Laurent et al. 2018, 2020; St Laurent and Kawahara 2019). This systematic body of work has therefore provided an understanding of the relative relationships of the two valid genera of Mimallonidae found in the United States and Canada, with *Lacosoma* being the type genus of Lacosominae and *Cicinnus* the type genus of Cicinninae; which are relatively distantly related within Mimallonidae.

Two mimallonid species inhabit the eastern United States and extreme southern Ontario east of the Great Plains: *L. chiridota* and *C. melsheimeri*. Although the majority of *C. melsheimeri* records are from the eastern United States, this species is quite widespread in the Rocky Mountains, although it is rarely collected in the region. A single, predominantly Mexican species reaches its northernmost extent in southern Arizona: *L. arizonicum* (Franclemont 1973; Powell and Opler 2009). *Lacosoma elassa* is only known from two specimens collected in Brownsville, Texas (Franclemont 1973).

In southern Arizona, *L. arizonicum* is a somewhat regularly collected, late night-flying denizen of mid-elevation oak forests, and its life history was recently published (Powell and Opler 2009; St Laurent et al. 2017). *Cicinnus* in contrast, is poorly represented in collections from Arizona and from the western United States in general. There is sparse literature and few collection records of *C. melsheimeri* from the Rocky Mountains and northern Arizona, New Mexico, western Texas and Mexico. Reports from southern Arizona are limited to recent online records (e.g., https://www.BugGuide.net). We discuss *Cicinnus* in southern Arizona, recognize the presence of a species there that is more closely related to the widespread Mexican species *C. mexicana* (Druce, 1898) than to *C. melsheimeri*, and describe it as new. This is the first new species of Mimallonidae described from North America since the 1970s, and only the second belonging to *Cicinnus* found in the United States.

The Sonoran Desert's Sky Islands Region is located at a biogeographic crossroads at the convergence of several biotic zones. Patterns of biodiversity are influenced by the ecological communities of the Sonoran and Chihuahuan Deserts, the Rocky Mountains, the Great Plains, the Sierra Madre and the Neotropics (Baynham 2012). The Sky Islands Region is characterized by an archipelago-like series of about 65 mountain ranges, each harboring isolated mid- and high-elevation oak and pine forests, surrounded by a sea of arid and semi-arid desert and grassland (Moore 2015). The onset of the summer monsoon influences the activity patterns of much of the region's biodiversity, prompting growth and reproduction in many plants, and prompting adult emergence and activity among many insect species (Ingram and Brusca 2015).

The combination of location, at the interface of biotic zones, the complex topography of the Sky Islands, and relative isolation of mountain range islands promotes unique ecological communities with high species diversity and endemism (Van Devender et al. 2013). Although the arthropod diversity of the region is relatively understudied (Moore et al. 2013), the moths of southeastern Arizona have been collected and documented for decades, and the region contains several classic collecting sites for moths and other insects including Box Canyon, Harshaw Creek, Madera Canyon, Peña Blanca Lake, and Ruby Road, among others. Many of these sites (e.g., Harshaw Creek, Madera Canyon) have been heavily collected by both amateur and professional entomologists for decades, with novel taxa being described from these localities (e.g., Lemaire et al. 1992; Donahue 1993).

Materials and methods

Taxonomic methods

All dissections performed for this study followed Lafontaine (2004) in methodology, with genitalia stored in glycerol-filled microcentrifuge vials. Genitalia of *Cicinnus* are incredibly intricate, complex, three dimensional structures, and therefore slide-mounting was not conducted in order to preserve the natural structural integrity. Labels of the holotype are given verbatim, with forward slashes used to denote separate labels.

Specimens examined are deposited in the collections listed below. Figures in this paper were created with Adobe Photoshop as part of the Creative Cloud (Adobe 2019), and maps were built using SimpleMappr (Shorthouse 2010). The following collections were used for specimens pertinent to the present study:

AMNH	American Museum of Natural History, New York, New York, USA;
BME	Bohart Museum of Entomology, University of California, Davis, California, USA;
BWC	B. Walsh Private Collection, Tucson, Arizona, USA;
CJM	Collection of José Monzón, Guatemala;
CRAS	Research collection of R. St Laurent, Gainesville, Florida, USA;
CUIC	Cornell University Insect Collection, Ithaca, New York, USA;
MCZ	Museum of Comparative Zoology, Harvard University, Cambridge, Massachusetts, USA;
MGCL	McGuire Center for Lepidoptera & Biodiversity, Gainesville, Florida, USA;
PJD	Collection of Paul J. Dennehy, Pennsylvania, USA;
VOB	Becker Collection, Camacã, Bahia, Brazil;

Molecular phylogenetics

We refer to the anchored hybrid enrichment (AHE) Mimallonidae phylogeny of St Laurent et al. (2020). While we do not conduct AHE analyses here, we discuss relationships of *Cicinnus* in this aforementioned work in order to bolster our understanding of the phylogenetic relationships of North American *Cicinnus*. In the present study we utilize sequences of the mitochondrial "barcoding" gene, cytochrome c oxidase subunit I (COI) in combination with morphology (Hebert et al. 2003). We sequenced 11 samples of *Cicinnus de novo*, and downloaded additional publicly available Cicinnini samples from BOLD (Barcode of Life Datasystems) (Ratnasingham and Hebert 2007) to compliment the material that we sequenced for this study. For *de novo* sequence data generation, one or two legs were removed from recently collected museum specimens and submitted to the Smithsonian Institution, Washington D.C. as part of the Smithsonian Institution DNA Barcode Network. Sequence assembly was conducted in Geneious v. 2019.2.1, and alignment performed with MUSCLE in AliView (Larsson 2014).

Maximum Likelihood (ML) phylogenetic analyses of unpartitioned COI data was performed using IQ-TREE v. 1.6.10, with branch supports reported as 1,000 Ultrafast Bootstraps (UFBoot) and SH-aLRT as a secondary measure of support (Nguyen et al. 2015; Hoang et al. 2018). The most optimal model of nucleotide evolution was selected by ModelFinder within IQ-TREE (Kalyaanamoorthy et al. 2017), and the TIM2+F+G4 model was used in 1,000 independent tree searches in IQ-TREE, the best scoring tree was used in Fig. 1 (and Suppl. material 1: Figure S1) and all discussions. Each of the 1,000 independent IQ-TREE runs also utilized UFBoot and SH-aLRT supports, as well as the -bnni option to further optimize UFBoot trees using Nearest Neighbor Interchange (NNI) in order to alleviate inherent biases of the UFBoot.

All sequence data provided by this study will be made available on GenBank, with applicable accession numbers provided in Suppl. material 2: Table S1. A COI FASTA alignment and tree file, including all taxa utilized in this study, are provided as Suppl. material 4: File S2 and Suppl. material 5: File S3 respectively.

Results and discussion

Cicinnus chambersi sp. nov.

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Figures 2, 3, 6, 7, 10, 11, 15, 16, 21

Type material. ***Holotype*****.** **United States of America – Arizona** • Arizona: Santa Cruz. Co., Peña Blanca Lake, Pajarito Mtns., Coronado NF; 750 W MV, 1000W MH, 31.402057, -111.084236, 21.VII.2015; leg. L.E. Reeves/ St Laurent dissection 2-20-17:1 *Cicinnus* sp./ St Laurent barcode 2-20-17:1 [barcode unsuccessful]/ St Laurent BC 5-6-19:1 [second barcode attempt]/ Holotype ♂ *Cicinnus chambersi* St Laurent, Reeves, Kawahara, 2020 [red label]/ (MGCL).

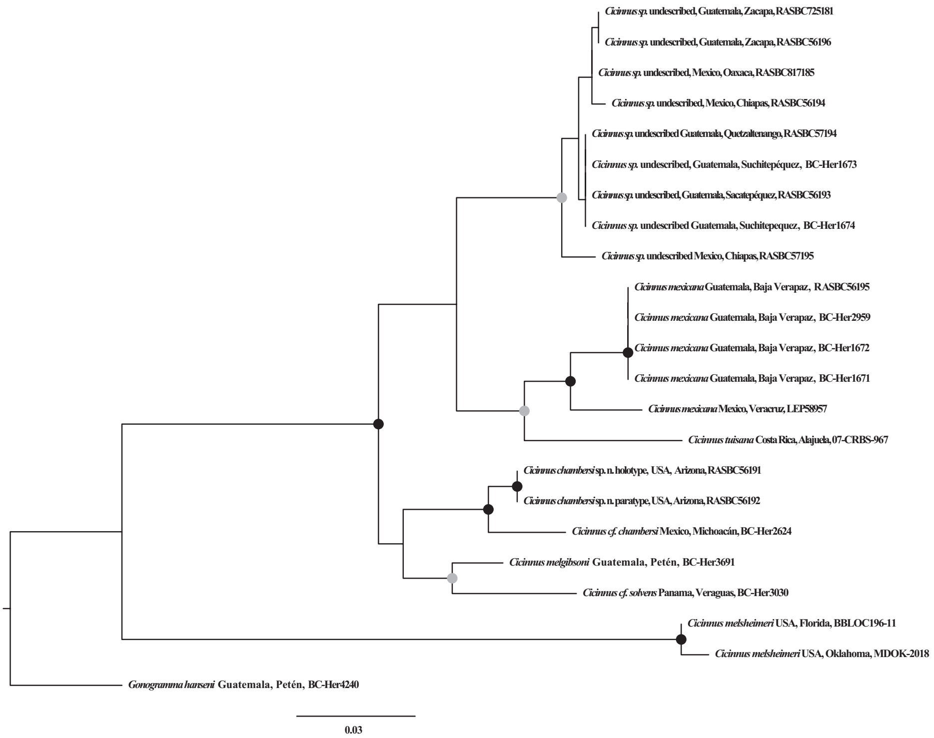


Figure 1. Maximum likelihood phylogenetic tree inferred with IQ-TREE based on the COI marker, rooted to *Gonogramma hanseni*. Black circles indicate SH-aLRT/UFBoot of 80/95 or greater for both values, and gray circles indicate SH-aLRT/UFBoot of 80–95 for both values. The scale bar represents expected number of nucleotide substitutions per site. See Suppl. material 1: Figure S1 for complete support values.

Paratypes. (3 ♂, 2 ♀ total) United States of America – **Arizona** – **Cochise County** • 1 ♀; Copper Canyon, Huachuca Mts; 31.363, -110.300; 6,000 ft [1,828 m]; 4.VII.2018; C.W. Melton [leg.]; photo ID no. 18070692, St Laurent dissection: 5-9-19:1; (MGCL). – **Santa Cruz County** • 1 ♂, 1 ♀; California Gulch, Pajarito Mountains; 31.422N, 111.245W; 3800 ft [1,158 m]; 27.VII.2017; J.B. Walsh leg.; MV/UV; (BWC) • 1 ♂; Peña Blanca Lake/ Ruby Rd area; 31°23'16"-24'N, 111°05'25"-07'W; 2–4.VIII.2017; James Adams & Lance Durden; light traps, LEP-58833 [MGCL AHE voucher number and St Laurent dissection number], St Laurent BC 5-6-19:2 [barcode]; (MGCL) • 1 ♂; Peña Blanca Canyon; 31.3844N, 111.0935W; 3.VIII.2017; P. Dennehy leg.; (PJD). Paratypes with the following yellow label: Paratype ♂/ ♀ *Cicinnus chambersi* St Laurent & Reeves, 2020.

Additional specimens [not included in type series]. United States of America – **Arizona** – **Santa Cruz County** • 2 ♂, 1 ♀; California Gulch; 31°25'18.33"N, 111°14'40.02"W; 3,790 ft [1,155 m]; 23.VII.2015 [2 ♂], 21.VII.2017 [1 ♀]; E. Rand leg. (Coll. E. Rand, Arizona) • 1 ♂; Peña Blanca Canyon; 31°23'18.38"N, 111°5'33.00"W; 3895 ft [1,187 m]; 17.VII.2009; E. Rand leg. (Coll. E. Rand, Ari-

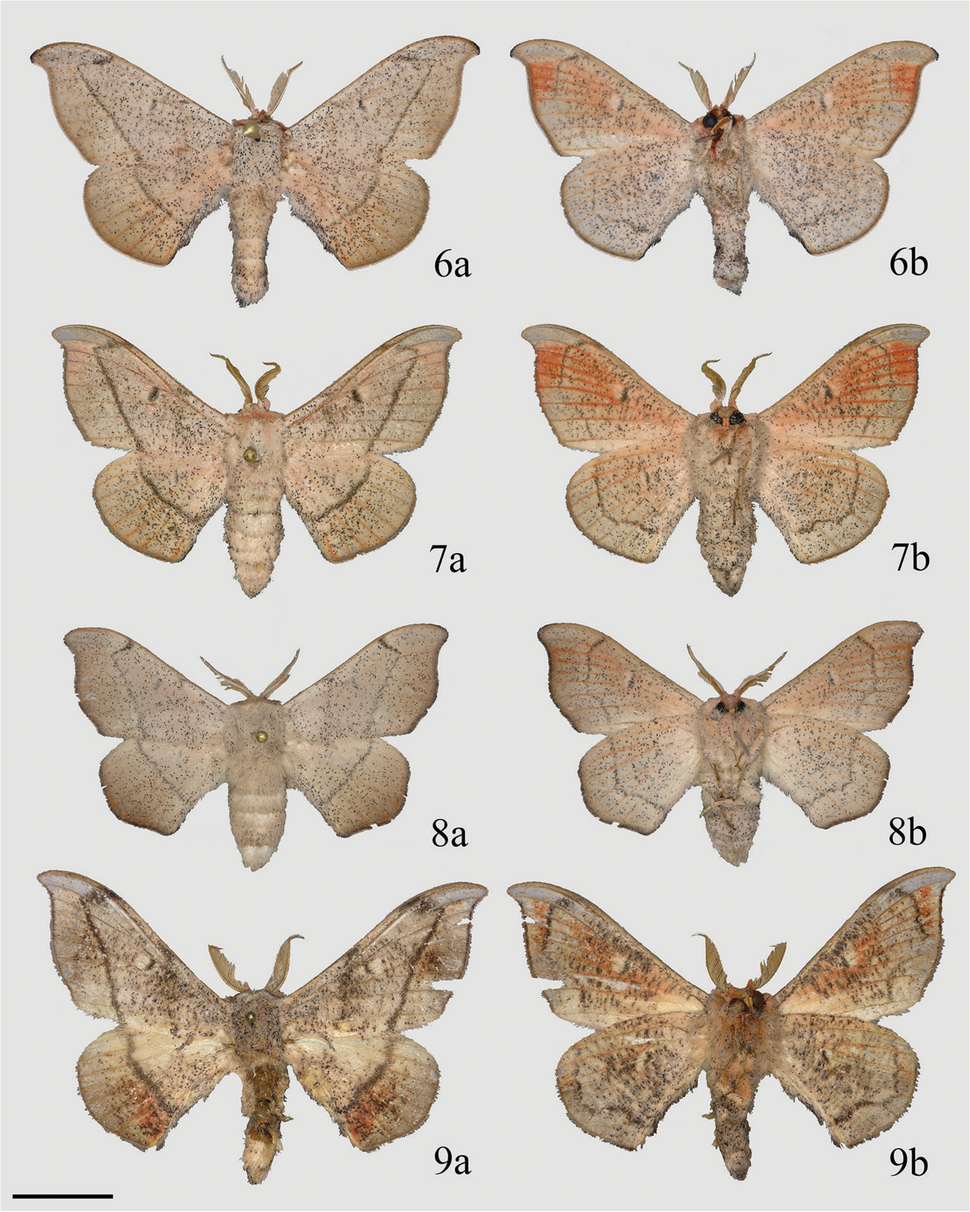
Figures 2–5. *Cicinnus* adult male forewing comparison showing the acuter angle of the postmedial line near the apex in *C. chambersi* than in *C. melsheimeri* **2** *C. chambersi* holotype, Arizona **3** *C. chambersi* paratype, Arizona **4** *C. melsheimeri*, Florida **5** *C. melsheimeri*, New Jersey. Scale bar: 1 cm.

zona) • 1 ♂; Jct. FR 49 & FR 812; 31°27'54.88"N, 110°43'9.94"W; 4960' [1,512 m]; 8.VII.2010; E. Rand leg. (Coll. E. Rand, Arizona).

Photographed individual [not collected and not included in type series]. United States of America – Arizona – Pima County • 1 ♀; Box Canyon; 31.799198, -110.798744; photographed by Salvador Vitanza, Entomologist (Identifier) at APHIS-PPQ, Arizona (Fig. 10).

Diagnosis. In southern Arizona, there are no other moths with which this species could be confused, the only other congener found in the United States, *C. melsheimeri*, has not been found to be sympatric with *C. chambersi*, but occurs farther north in mountainous northern Arizona, north of the Mogollon Rim, and northeast into central and northern New Mexico. Because *C. chambersi* and *C. melsheimeri* are both found in Arizona, we compare them here, although they are not each other's closest relatives within *Cicinnus* (see remarks later).

Cicinnus melsheimeri is a somewhat variable species, usually with brown shaded regions along the wing margins, in comparison, *C. chambersi* is more consistently uniformly pink in coloration with a homogenous ground color. The apex of the forewing



Figures 6–9. Adult ♂ *Cicinnus* **a** dorsal **b** ventral **6** *C. chambersi* holotype, USA, Arizona, Santa Cruz Co., Peña Blanca Lake, Pajarito Mtns., Coronado National Forest (MGCL) **7** *C. chambersi* paratype, USA, Arizona, Santa Cruz Co., Peña Blanca Lake/ Ruby Rd area (MGCL) **8** *C. melsheimeri*, USA, Florida, Alachua Co., Micanopy (MGCL) **9** *C. chabaudi*, Mexico, Oaxaca, ca. 15 km SE San Martín Huamalulpan, Cabañas Yucunuvichi (MGCL). Scale bar: 1 cm.

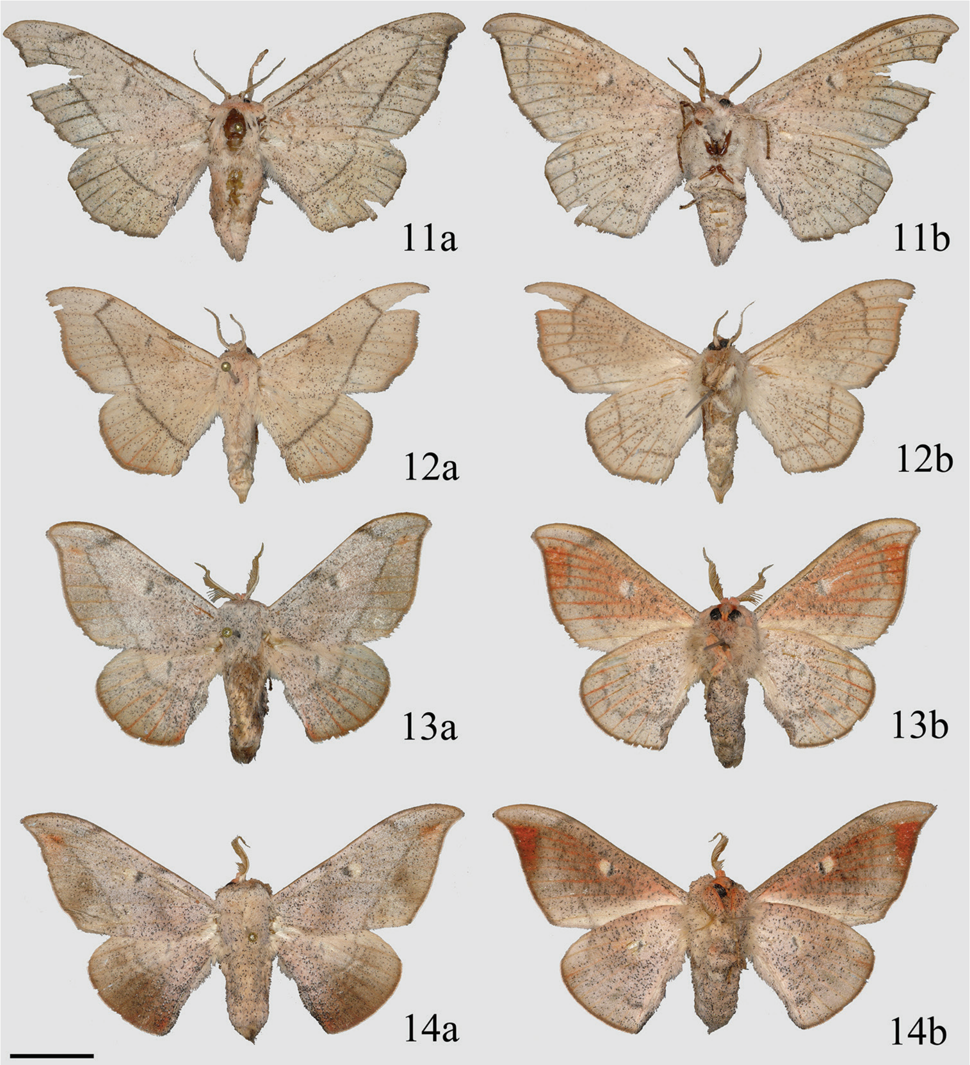
of *C. chambersi* is much sharper than in *C. melsheimeri*, and the postmedial line of the forewing more distinctly forms a right or acute angle near the apex of the forewing, whereas this same angle is more obtuse in *C. melsheimeri* (see Figs 2–5, where males are

Figure 10. Living adult ♀ *Cicinnus chambersi*. USA, Arizona, Pima Co., Box Canyon, photographed by Salvador Vitanza, Entomologist (used with permission) **a** dorsal **b** anterior **c** lateral.

shown, the same distinction is observed in females as well. Line thickness and development of discal spots are rather variable characteristics in both species).

Genitalia of the two species of *Cicinnus* in Arizona are structurally very distinct, although they both have the characteristics deemed apomorphic of *Cicinnus sensu stricto* as defined by St Laurent and Kawahara (2019). Fundamental differences in male genitalia of the two species in question are: *C. melsheimeri* bears elongated vincular arms (Fig. 17) which are naturally held along a ventral channel on the valvae, *C. chambersi* and all other *Cicinnus* lack vincular arms; the valvae of both *C. melsheimeri* and *C. chambersi* are mostly membranous, but in *C. melsheimeri* they are even more so and are dorso-ventrally wider than laterally, whereas in *C. chambersi* the valvae are squarer with a more substantially sclerotized costal half; the juxtal complex in *C. chambersi* is bifurcated on either side of the phallus but ends in a singular upward curling terminus on either side of the phallus in *C. melsheimeri*. Female genitalia of *C. chambersi* are typical of *Cicinnus*, differing from those of *C. melsheimeri* by the narrower dorsal projection of the VIII segment, more well-developed anterior and posterior apophyses, a ductus bursae that is at least five times longer in length, and an elongated corpus bursae that is roughly four times the length of that of *C. melsheimeri* (compare Figs 21, 23).

The differences between *C. chambersi* and the other Mexican *Cicinnus* species are less obvious. The only names currently applied to similar Mexican species are *C. chabaudi* Dyar, 1914 (Figs 9, 18), and *C. mexicana* (Figs 14, 20), the latter which includes at least two cryptic species (see remarks and additional discussion below). *Cicinnus chabaudi* is restricted to arid south-central Mexico in the vicinity of the Distrito Federal, this species is more darkly maculated than *C. chambersi* with deep reddish-brown anal areas of the hindwings. *Cicinnus mexicana* is a variable species, often with



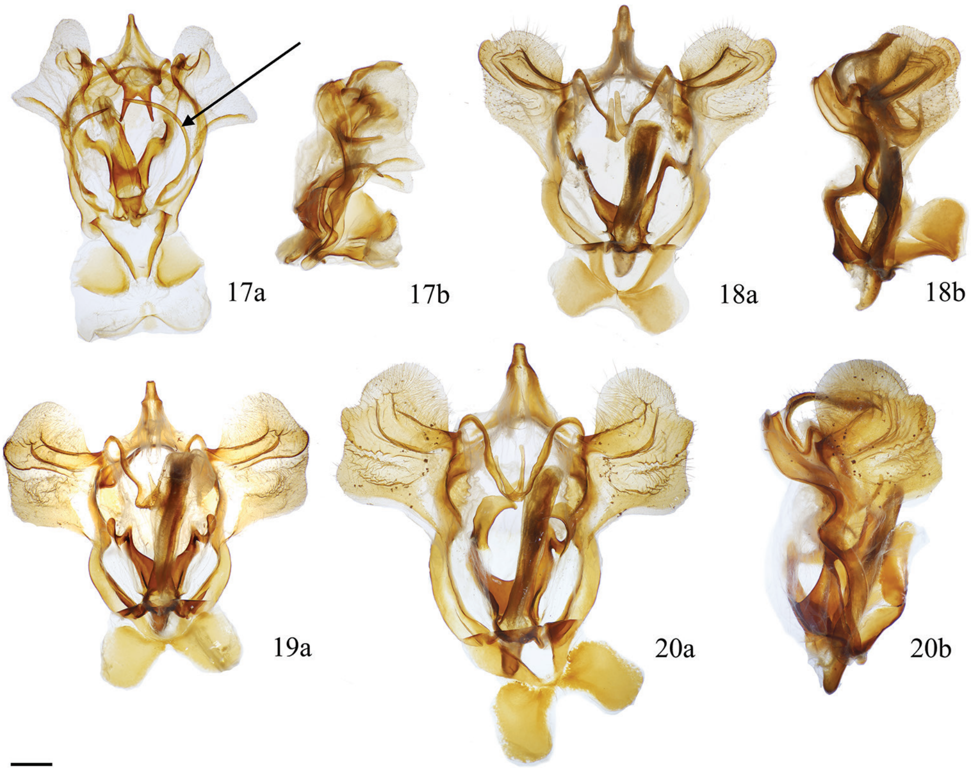
Figures 11–14. Adult *Cicinnus* **a** dorsal **b** ventral **11** *C. chambersi* ♀ paratype, USA, Arizona, Cochise Co., Copper Canyon, Huachuca Mts, 1828 m (MGCL) **12** *C. melsheimeri* ♀, USA, Texas, Cameron Co., Brownsville (MGCL) **13** *C.* undescribed near *mexicana* ♂, Guatemala, Zacapa, Sierra de las Minas, N Rio Hondo, E San Lorenzo, Cerro Monos env., 2243 m (MGCL) **14** *C. mexicana* ♂, Guatemala, Baja Verapaz, SE Purulhá, Ranchitos de Quetzal, Parque Ecológico Gucumatz, 1660 m (MGCL). Scale bar: 1 cm.

deep reddish-brown submarginal areas of the forewings and straighter wing margins (all previously discussed *Cicinnus* species have convex forewing margins), but some populations are lighter with more convex forewing margins. The male genitalia of these various Mexican *Cicinnus* are quite similar with only minor differences from species to species with the most useful characters in this particular group (valvae shape and juxtal complex) displaying intraspecific variation (compare *C. chambersi* to the others:

Figures 15, 16. *Cicinnus chambersi* ♂ genitalia **a** ventral, vinculum extension in natural position, deciduous setae intact **b** ventral, vinculum extension in natural position, deciduous setae removed **c** ventral, vinculum extension held open **d** lateral **15** holotype, USA, Arizona, Santa Cruz Co., Peña Blanca Lake, Pajarito Mtns., Coronado National Forest, St Laurent dissection: 2-20-17:1 (MGCL) **16** paratype, USA, Arizona, Santa Cruz Co., Peña Blanca Lake/ Ruby Rd area, St Laurent dissection: LEP58833 (MGCL). Scale bar: 1 mm.

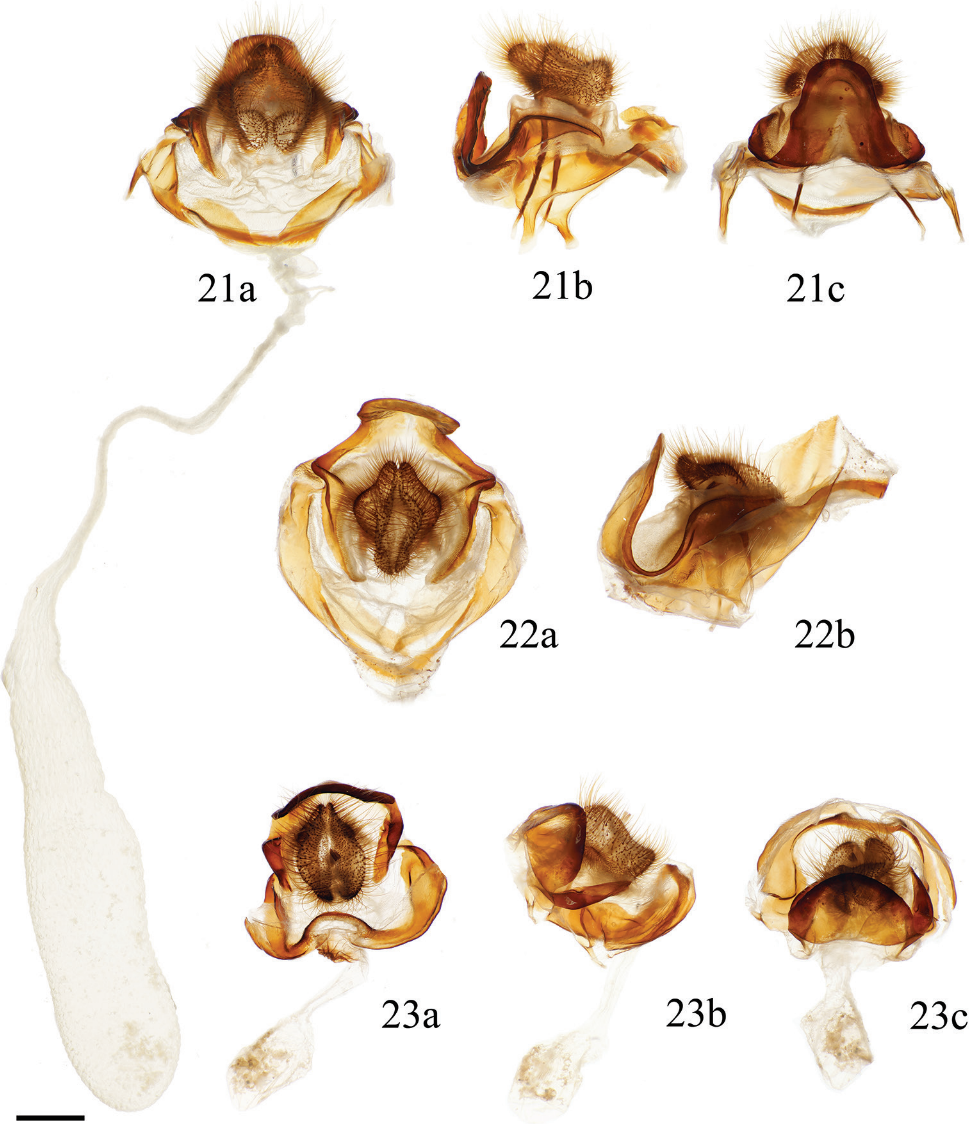
Figs 15, 16 to 18–20; and the two *C. chambersi* specimens figured in Figs 15, 16 to each other). *Cicinnus chambersi* however, can be recognized by the squarer shape of the valvae, which are generally more rounded and splayed upward in other Mexican *Cicinnus*. The intricacies of the taxonomy of *Cicinnus* in Mexico is discussed below in the remarks and further discussion sections.

Description. Male. ***Head*:** Coloration pinkish beige with an ample speckling of dark brown petiolate scales. Antennae pale yellow with a covering of beige scales, occasionally speckled with darker brown scales, bipectinate to tip, distal quarter of pectinations dramatically shorter than basal three quarters of pectinations. Eyes very large, comprising more than two thirds area of head. Labial palpus exceedingly short, not extending beyond frons, coloration as for head though with darker gray scales dorsally; labial palpus apparently three-segmented though distalmost segment miniscule.



Figures 17–20. *Cicinnus* ♂ genitalia **a** ventral, vinculum extension held open **b** lateral **17** *C. melsheimeri*, USA, Ohio, Geauga Co., Thompson Township, St Laurent dissection: 8-10-18:1 [arrow denotes vincular arms which are unique to *C. melsheimeri* among *Cicinnus*] (MGCL) **18** *C. chabaudi*, Mexico, Oaxaca, ca. 15 km SE San Martín Huamalulpan, Cabañas Yucunuvichi, St Laurent dissection: 8-10-18:3 (MGCL) **19** *C.* undescribed near *mexicana* Guatemala, Zacapa, Sierra de las Minas, N Rio Hondo, E San Lorenzo, Cerro Monos env., 2243 m, St Laurent dissection: 7-25-18:1 (MGCL) **20** *C. mexicana*, Guatemala, Baja Verapaz, SE Purulhá, Ranchitos de Quetzal, Parque Ecológico Gucumatz, 1660 m, St Laurent dissection: 7-25-18:4 (MGCL). Scale bar: 1 mm.

***Thorax*:** Dorsally light beige with profuse speckling of dark brown petiolate scales, prothorax lighter in color, pinker, ventrally thorax as above. ***Legs*:** Coloration mostly as for thorax. Tibial spurs small, about as long as one quarter length of first tarsomere. ***Forewing dorsum*:** Forewing length: 20–22 mm, avg.: 21 mm; wingspan: 39–45 mm, *N* = 3. Triangular, apex sharply falcate, outer margin mostly convex except for concavity below apex and slight tornal concavity. Ground color same light beige as thorax, with underlying pink hue throughout, profusely speckled with dark brown petiolate scales which are less densely distributed submarginally. Antemedial line very faint, usually nonexistent but if present diffuse and wavy. Postmedial line fine, almost always nearly straight, well-defined, dark brown, perpendicularly angled toward costa after passing Rs4, line thickness variable but comparatively thicker near costa. Entire wing nearly concolorous except for postmedial line and discal spot though coloration grayer



Figures 21–23. *Cicinnus* ♀ genitalia **a** ventral **b** lateral **c** dorsal **21** *C. chambersi* paratype, USA, Arizona, Cochise Co., Copper Canyon, Huachuca Mts, 1828 m, St Laurent dissection: 5-9-19:1 (MGCL) **22** *C.* undescribed near *mexicana*, Mexico, Chiapas, San Cristobal de las Casas env., nr. Hotel Flores, 2415 m, St Laurent dissection: 5-6-19:4 [note: ductus and corpus bursae not shown, but highly elongate as in Fig. 22] (MGCL) **23** *C. melsheimeri*, USA, Indiana, Brown Co., Brown County State Park, St Laurent dissection: 5-11-19:1 (MGCL). Scale bar: 1 mm.

rather than pink along costa, especially apically. Discal spot variably developed ranging from faint comma-like mark to well-developed gray-brown oval situated at distal margin of discal cell. Fringe darker brown than ground color of wing. ***Forewing ventrum*:**

Ground color similar to dorsum but suffused with bright orange-red especially medially and along veins, basally wing much pinker than dorsally. Bright orange-red patch of scales present submarginally between Rs3–M3. Postmedial line weakly defined, consisting of dentate, convex line that is neither straight nor distinctly angled toward costa. Discal spot may be more well-defined than on dorsum. ***Hindwing dorsum*:** Rounded, coloration and patterning as for forewing dorsum, but antemedial line absent, postmedial line outwardly convex, discal spot less defined. ***Hindwing ventrum*:** Follows similar pattern as forewing ventrum, postmedial line convex and more interrupted by veins than on dorsum, discal spot weakly developed. ***Abdomen*:** Robust, extending beyond anal angle of hindwing, coloration mostly as for thorax. Sternite of VIII anteriorly and posteriorly concave, with pair of short protuberances, one on either side of posterior concavity. ***Genitalia*:** (Figs 15, 16) *N* = 2. Complex, though typical of *Cicinnus*. Vinculum rectangular with pair of ventral apodemes. Tegumen triangular but not particularly distinct from uncus. Uncus simple, triangular, ventrally with blunt apex, but appearing sharp laterally due to distal flattening. Gnathos originating from between base of uncus and dorsal junction of valvae with vinculum, gnathos swoops downward from origination point to central location below uncus, distally gnathos extends as pair of fingerlike projections. Valvae mostly membranous with sclerotization restricted to upper region of valvae, particularly along mesal bar that extends outward along length of valvae, valvae rectangular in shape, small relative to remainder of genitalia. Juxta fused to phallus, extending laterally on either side of phallus with pair of sclerotized projections curling upward. Phallus cylindrical, mostly membranous. Vesica bag-like. Base of vinculum extends outward as two heavily sclerotized arms ending in bilobed, thin, sclerotized structure which is naturally curled upward covering genitalia, within which densely packed setae stored (Fig. 15a). **Female. *Head*:** As for male in coloration but antennae appearing longer, comparatively thinner due to much shorter pectinations along length, pectinations gradually decrease in length from base to tip of antenna. ***Thorax*:** As for male. ***Legs*:** As for male but tibial spines much longer, at least double length of those of male. ***Forewing dorsum*:** Forewing length: 28 mm; wingspan: 60 mm, *N* = 1. As for male but wing shape slightly wider and more elongated, hue of wing lighter than in male. ***Forewing ventrum*:** Similar to dorsum, lacking any deep orange-red coloration of male. Antemedial line absent, postmedial line weakly defined, consisting of dentate, convex line. Discal spot about as well-defined as on dorsum. ***Hindwing dorsum*:** As for male, coloration barely lighter. ***Hindwing ventrum*:** Follows similar pattern as forewing ventrum, postmedial line convex, discal spot nearly absent. ***Abdomen*:** As for male, but more robust, coloration mostly as for thorax. ***Genitalia*:** (Fig. 21) *N* =1. Tergite VIII forms smooth, heavily sclerotized, posteriorly directed tongue-like extension which nearly reaches distalmost apex of papillae anales. Apophyses anteriores roughly one third length of apophyses posteriores, much thicker, stouter. Lamella antevaginalis weakly sclerotized and split mesally, lamella postvaginalis a more heavily sclerotized band but not as wide as lamella postvaginalis. Ductus bursae very long, narrow, about twice length of remainder of genitalia. Corpus bursae narrow, tubular, longer than ductus bursae; ductus and corpus bursae together about as long as entire abdomen. Papillae anales widest mesally, distally pinched together and somewhat projected upward, overall densely covered in elongate setae.

Biology. The life history of *C. chambersi* is unknown, but we expect the larvae feed on oaks (*Quercus* spp. Linnaeus) as do all Mimallonidae in Canada and the United States for which larval hosts are known. *Cicinnus chambersi* appears to be a denizen of mid-elevation oak-dominated habitats of the Sky Island Region. The type series and other examined specimens were collected at elevations ranging from 1,155 m to 1,828 m, all within the oak belt of sky island mountain ranges (Baynham 2012). This narrow elevation range suggests possible specialization on certain oak species that are also restricted in elevation, as is seen in other oak-feeding, elevation-restricted Lepidoptera in the region (C. Schmidt pers. comm.). Habitats at these localities vary somewhat and include Madrean oak woodland and oak grasslands. We are unaware of collections of this moth in higher elevation oak-pine woodland habitats. *Cicinnus chambersi* is a typical summer monsoon moth, flying from early July to early August. Mimallonid larvae take several months to mature in North America, therefore those interested in locating the larvae should look for mature larvae on oaks in the autumn.

Distribution. *Cicinnus chambersi* is known only from sky island mountain ranges of southeastern Arizona (Figs 24, 25). The type series is restricted to Arizona material, but undoubtedly *C. chambersi* occurs in mountain ranges with similar oak-dominated habitats in northwestern Mexico. See below for a more in-depth discussion of additional specimens from Mexico. *Cicinnus chambersi* has been collected in the Huachuca, Pajarito, Patagonia, and Santa Rita Mountains, with the northernmost observation being Box Canyon on the northern edge of the Santa Rita Mountains (Pima County).

Etymology. This new species is named for Aaron Chambers of Tucson, Arizona, a desert dweller and dear friend of the authors, in recognition of his support of native biodiversity and for imparting his expansive ecological knowledge of the Sonoran Desert to us every monsoon season.

Remarks. It is surprising that *C. chambersi* has been overlooked in North America due to the distinct morphological differences between *C. chambersi* from Arizona and the common *C. melsheimeri* with which the new species has been confused. However, *C. chambersi* appears to be a rarely collected moth considering the few specimens known to us and the intensity at which insect collecting occurs in southern Arizona, and this could be the reason *C. chambersi* has not yet been described. To our knowledge, no specimens of *C. chambersi* were available to Franclemont at the time of his 1973 revision (St Laurent pers. obs. of the Cornell University Insect Collection). In fact, we are not aware of any specimens collected in the United States prior to 2009. Therefore, it is also possible that *C. chambersi* is a relatively recent establishment from Mexico in southern Arizona.

Apart from the differences between *C. chambersi* and *C. melsheimeri* revealed by genitalia dissections, ongoing phylogenomic work using anchored hybrid enrichment (Lemmon et al. 2012), in which hundreds of conserved loci have been sequenced for nearly all described genera of Mimallonidae, have shed light on the relative relationships of species within *Cicinnus*. *Cicinnus melsheimeri*, *C. chambersi* and its putative

Figure 24. Type locality of *Cicinnus chambersi*, Arizona, Santa Cruz Co., Peña Blanca Lake, Pajarito Mtns., Coronado National Forest. Photo courtesy of Aaron Chambers.

sister species, *C.* cf. *mexicana*, have been included in the phylogenomic work of St Laurent et al. (2020). In these authors' study (see their fig. 2), *C. melsheimeri* is sister to the remainder of *Cicinnus*, with *C.* cf. *orthane* (type species of *Cicinnus*) sister to *C. chambersi* + *C.* cf. *mexicana* (all relationships with 100% support). This topology is supported by our morphological study, in that *C. melsheimeri* is the most distinct *Cicinnus* species and is the only one to bear vincular arms (Fig. 17), with all other known *Cicinnus* species lacking them. Our barcoding efforts carried out for the present study have revealed what are essentially identical topological relationships (Fig. 1) as in St Laurent et al. (2020), albeit with lower UFBoot support than in the phylogenomic work which utilizes much more substantial, genomic, datasets. Regardless, important takeaways are illustrated by the COI ML tree here, which recovers *C. melsheimeri* sister to all other *Cicinnus*; with the cicinnine *Gonogramma hanseni* (Herbin & Monzón, 2015) used to root this tree. The holotype and a paratype of *C. chambersi* have been barcoded and are presented in the tree in Fig. 1 in this work; and form a clade sister to two other Central American *Cicinnus*: *C. melgibsoni* Herbin & Monzón, 2015 and *C.* cf. *solvens* Dyar, 1914. This clade together is sister to a densely sampled *C. mexicana sensu lato* clade which also includes the Central American *C. tuisana* Schaus, 1910, a species remarkably similar in external appearance to

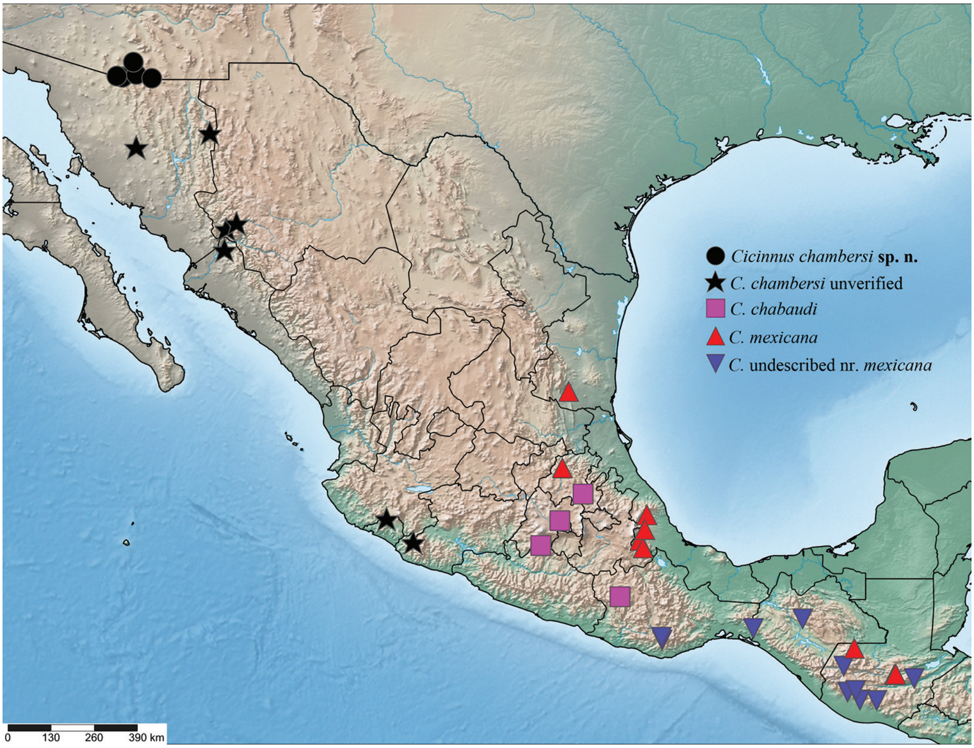


Figure 25. Map depicting localities of *C. chambersi* and species related to *C. mexicana* examined in the present study. See the Suppl. material 3: File S1 for full data for all points.

C. mexicana. We recognize that two distinct entities exist under the name *C. mexicana* (which together are not monophyletic), with the clade containing topotypical *C. mexicana* from Veracruz, Mexico being here considered *C. mexicana sensu stricto*. True *C. mexicana*, therefore, is sister to *C. tuisana*, a similar species found in Costa Rica and Panama, in our COI ML analysis. The other clade is unnamed at this time pending ongoing taxonomic work of the genus; but it suffices to say that morphology, phylogenomic, and mitochondrial evidence all support a closer relationship between the newly described *C. chambersi* and Central American *Cicinnus* species, than to the unique, largely North American *C. melsheimeri*.

Cicinnus in Mexico, further discussion

In describing *C. chambersi*, it is necessary to go into some additional depth in discussing the *Cicinnus* of Mexico in order to couch the new species within the broader context of its conspecifics in the region, where several described and undescribed taxa are found. The common North American *C. melsheimeri*, discussed above in the diagnosis of *C. chambersi* and in the phylogenetic justification for the validity of the new species, also appears to be found in Mexico. *Cicinnus melsheimeri* is found throughout the eastern United States and southeastern Canada, with sparse records in the Rocky Mountains and the western United States (Colorado, Utah, northern Arizona, central and northern New Mexico, and the Big Bend Region of western Texas, and southern Texas) (St Laurent unpublished). Additional populations of a taxon near *C. melsheimeri* are known from throughout the mountainous regions of Mexico (in Chihuahua, Distrito Federal, Hidalgo and Nuevo Leon) as well, these specimens display the typical genitalia of *C. melsheimeri* complete with the vincular arms (NHMUK dissection NHMUK010402293 of a specimen from Hidalgo, examined). The degree of cryptic diversity included under the name *C. melsheimeri* is yet to be fully resolved, though this will be a worthy area of research. It is clear however, that true *C. melsheimeri* (type locality, Pennsylvania, USA), which we here consider to include all populations morphologically most similar to the eastern USA species, as well as those in Mexico, can be readily differentiated from the remainder of *Cicinnus* (including *C. chambersi*) by the vincular arms that are present in the male genitalia. *Cicinnus melsheimeri* has been shown to represent a distinct lineage of *Cicinnus* sister to the remainder of the genus within a phylogenomic (St Laurent et al. 2020) and mitochondrial barcoding context (this paper).

Other *Cicinnus* populations in Mexico, including *C. chambersi* which ranges as far north as southern Arizona, belong to the more typical, primarily tropical American group of *Cicinnus* that always lack vincular arms in the male genitalia. This putative species-group contains all *Cicinnus sensu stricto* (*sensu* St Laurent and Kawahara 2019) except *C. melsheimeri*. In Mexico, only three named species are known: *C. chabaudi* (Figs 9, 18), *C. melgibsoni*, and *C. mexicana* (Figs 14, 20). *Cicinnus chabaudi* is restricted to arid south-central Mexico in the vicinity of Distrito Federal (extending at least to northwestern Oaxaca as per a specimen in CRAS). *Cicinnus melgibsoni* was described from Guatemala but is also found in southern Mexico (Herbin and Monzón 2015). The widespread *C. mexicana* was described from Orizaba, Veracruz, Mexico. The first author has examined numerous *C. mexicana* from near the type locality of this species as well as throughout Mexico, Guatemala, and Belize. Preliminary morphological studies and barcoding conducted herein suggest that there are at least two putative species under the name *C. mexicana*, but they do not form a monophyletic group. One putative species, *C. mexicana sensu stricto*, is found in eastern and southern Mexico, on the eastern slopes of the Sierra Madre Oriental into central Guatemala (Baja Verapaz); and a second, undescribed, species occurs in southern Mexico (Chiapas and Oaxaca) and southern Guatemala. We do not describe the southern populations as a new taxon here, pending ongoing studies of *Cicinnus*, as it will be necessary to include additional populations. For example, the Costa Rican species *C. tuisana* also falls into this broader *C. mexicana sensu lato* clade (Fig. 1) introducing additional uncertainty about the identity of these taxa. Despite these issues however, *C. chambersi* is morphologically, genetically, and biogeographically distinct from any of these other taxa.

In northwestern Mexico there exists no name to adequately refer to *Cicinnus* species there, except for specimens clearly more allied to *C. melsheimeri* as discussed previously. Therefore, *C. chambersi* is the first named species belonging to the typical Neotropical *Cicinnus* species-group described from the arid southwestern United States and (likely) northwestern Mexico. We are aware of five specimens of *Cicinnus* from northwestern Mexico that are morphologically similar to *C. chambersi* but are from scattered localities with inadequate numbers of specimens from each location to allow for a convincing determination as *C. chambersi*. These specimens were also not barcoded. Therefore, none of these specimens are included in the type series of *C. chambersi* in order to conservatively restrict the type series to specimens collected at and around the type locality in southern Arizona. Each of the five northwestern Mexican specimens will be discussed below in order to bring attention to them in hopes that additional material will be discovered or collected to better determine their identities. Complete collecting data, including institutional depositions, for these specimens can be found in the supplemental appendix (Suppl. material 3: File S1).

One male specimen from the AMNH bears a label reading "Horcasitas." We believe this refers to San Miguel de Horcasitas in Sonora, though admittedly the data are poorly documented. Externally this specimen resembles *C. chambersi* but has straighter forewing margins and is in otherwise poor condition. The genitalia differ from *C. chambersi* with the valvae of the Horcasitas specimen more rounded and curved upwards, which is more typical of *C. mexicana*.

In the BME there are two apparently conspecific male specimens from Chihuahua, one from Temoris and another from Cuiteco, and a putatively conspecific female from Choix, Sinaloa. While these Chihuahuan males are externally very similar to *C. chambersi* from Arizona, and inhabit comparable habitats, the female from nearby Choix displays a postmedial line angled differently from any examined female *C. chambersi*, and thus makes the determination of the Chihuahuan males as *C. chambersi* inconclusive (if the two males and the female are regarded as conspecific).

A single large male from the AMNH with the following data is also worth discussing: Mexico, Sonora, Mile 6.2, Colonia Mesa Tres Ríos to Huachinera. This specimen is larger and paler than any examined *C. chambersi*, and from farther east than any other putative Mexican *C. chambersi*.

Finally, a single male from Minatitlán, Colima (in VOB) and a single female from nearby Michoacán (Barcode of Life Datasystems, BC-Her2624) are known, which are morphologically more similar to *C. chambersi* than *C. mexicana* and may represent another undescribed species near *C. chambersi* or the southern extent of the distribution of this species. We were unable to examine the genitalia of this population, though a barcode of the Michoacán specimen places it sister to *C. chambersi* (see Fig. 1) in our analysis, supporting the hypothesis that they are closely related or perhaps even conspecific with *C. chambersi*. We hope that additional collecting in these regions will help elucidate the distribution of *C. chambersi* in Mexico, as well as to clarify the specific identities of the abovementioned specimens from Chihuahua, Colima, Michoacán, Sonora, and Sinaloa.

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References

Baynham P (2012) Threats to Sky Island communities of southeastern Arizona. Desert Plants 28: 22–27.

Blanchard E (1852) Insectos, Orden VI, Lepidopteros. In: Gay C (Ed.) Historia Física y Política de Chile. Zoología, 7. The author, Paris, 1–112.

Donahue JP (1993) Six species of tiger moths (Arctiidae: Lithosiinae, Cteneuchinae) new to the United States fauna, with notes on their nomenclature and distribution in Middle America. Journal of the Lepidopterists' Society 47: 199–210.

Druce H (1898) Lepidoptera, Heterocera II. In: Godman FD, Salvin O (Eds) Biologia Centrali-Americana; contributions to the knowledge of the fauna of Mexico and Central America. R. H. Porter, London, 622 pp.

Dyar HG (1898) New American moths and synonymical notes. Journal of the New York Entomological Society 6: 33–44.

Dyar HG (1914a) Descriptions of new species and genera of Lepidoptera from Mexico. Proceedings of the United States National Museum 47: 365–409. https://doi.org/10.5479/si.00963801.47-2054.365

Dyar HG (1914b) Report on the Lepidoptera of the Smithsonian Biological Survey of the Panama Canal Zone. Proceedings of the United States National Museum 47: 139–350. https://doi.org/10.5479/si.00963801.47-2050.139

Franclemont JG (1973) Mimallonoidea (Mimallonidae) and Bombycoidea (Apatelodidae, Bombycidae, Lasiocampidae). Fasc. 20.1. In: Dominick R, Ferguson D, Franclemont J, Hodges R, Munroe E (Eds) The Moths of America North of Mexico. E.W. Classey Ltd. and Richard B. Dominick Publ, London, 86 pp.

Grote AR (1864) Descriptions of North American Lepidoptera, No. 3. Proceedings of the Entomological Society of Philadelphia 3: 73–92.

Harris TW (1841) Art. XV.- Remarks on some North American Lepidoptera. The Entomologist 7: 97–101.

Hebert PDN, Cywinska A, Ball SL, DeWaard JR (2003) Biological identifications through DNA barcodes. Proceedings of the Royal Society B: Biological Sciences 270(1512): 1–9. https://doi.org/10.1098/rspb.2002.2218

Herbin D, Monzón J (2015) Description of four new species of Mimallonidae and four new species of Apatelodidae from the El Mirador Basin in northern Guatemala. Antenor 2: 176–197.

Hoang DT, Chernomor O, von Haeseler A, Minh BQ, Vinh LS (2018) UFBoot2: Improving the Ultrafast Bootstrap approximation. Molecular Biology and Evolution 35: 518–522. https://doi.org/10.1093/molbev/msx281

Ingram M, Brusca RC (2015) Desert Storms. In: Dimmitt MA, Comus PW, Brewer LM (Eds) A Natural History of the Sonoran Desert. Arizona-Sonoran Desert Museum Press, Tucson, 45–54.

Kalyaanamoorthy S, Minh BQ, Wong TKF, von Haeseler A, Jermiin LS (2017) ModelFinder: fast model selection for accurate phylogenetic estimates. Nature Methods 14: 587–589. https://doi.org/10.1038/nmeth.4285

Lafontaine JD (2004) Noctuoidea: Noctuidae (part). Noctuinae (part – Agrotini). Fasc. 27.1. In: Dominick R, Ferguson D, Franclemont J, Hodges R, Munroe E (Eds) The Moths of America North of Mexico, Fasc. 20.1. Wedge Entomological Research Foundation, Washington, 385 pp.

Larsson A (2014) AliView: a fast and lightweight alignment viewer and editor for large datasets. Bioinformatics 30: 3276–3278. https://doi.org/10.1093/bioinformatics/btu531

Lemaire C, Smith MJ, Wolfe KL (1992) A new *Automeris* from Arizona, including its life history and notes on the *Automeris colenon* complex. Tropical Lepidoptera 3: 123–129.

Lemmon AR, Emme SA, Lemmon EM (2012) Anchored Hybrid Enrichment for massively high-throughput phylogenomics. Systematic Biology 61: 727–744. https://doi.org/10.1093/sysbio/sys049

Moore W (2015) Sky Islands. In: Dimmit MA, Comus PW, Brewer LM (Eds) A Natural History of the Sonoran Desert. Arizona-Sonoran Desert Museum Press, Tucson, 20–23.

Moore W, Meyer, III WM, Ebel JA, Franklin K, Wiens JF, Brusca RC (2013) Systematics, biogeography, ecology, and population genetics of arthropods of the Madrean Sky Islands. In: Gottfried GJ, Folliot PF, Bebow BS, Eskew LG (Eds) Merging Science and Management in a Rapidly Changing World: Biodiversity and Management of the Madrean Archipelago III. U.S. Department of Agriculture RMRS-P-67, 140–164.

Nguyen L-T, Schmidt HA, von Haeseler A, Minh BQ (2015) IQ-TREE: A fast and effective stochastic algorithm for estimating maximum-likelihood phylogenies. Molecular Biology and Evolution 32: 268–274. https://doi.org/10.1093/molbev/msu300

Powell JA, Opler PA (2009) Moths of Western North America. University of California Press, Berkeley, 383 pp. https://doi.org/10.1525/california/9780520251977.001.0001

Ratnasingham S, Hebert PDN (2007) Bold: The Barcode of Life Data System (http://www.barcodinglife.org). Molecular Ecology Notes 7: 355–364. https://doi.org/10.1111/j.1471-8286.2007.01678.x

Schaus W (1910) XLIV.-New species of Heterocera from Costa Rica. II. The Annals and magazine of natural history, including zoology, botany, and geology 6: 402–422. https://doi.org/10.1080/00222931008692867

Shorthouse DP (2010) SimpleMappr, an online tool to produce publication-quality point maps. http://www.simplemappr.net [accessed 1/17/2020]

St Laurent RA, Hamilton CA, Kawahara AY (2018) Museum specimens provide phylogenomic data to resolve relationships of sack-bearer moths (Lepidoptera, Mimallonoidea, Mimallonidae). Systematic Entomology 43: 729–761. https://doi.org/10.1111/syen.12301

St Laurent RA, Kawahara AY (2019) Reclassification of the sack-bearer moths (Lepidoptera, Mimallonoidea, Mimallonidae). ZooKeys 815: 1–114. https://doi.org/10.3897/zookeys.815.27335

St Laurent RA, Mielke CGC, Herbin D, Dexter KM, Kawahara AY (2020) A new target capture phylogeny elucidates the systematics and evolution of wing coupling in sack-bearer moths. Systematic Entomology. https://doi.org/10.1111/syen.12421

St Laurent RA, Wagner DL, Reeves LE, Kawahara AY (2017) Notes on the larva and natural history of *Lacosoma arizonicum* Dyar (Mimallonoidea, Mimallonidae) with new host and parasitoid records. Journal of the Lepidopterists' Society 71: 177–181. https://doi.org/10.18473/lepi.71i3.a9

Van Devender TR, Avila-Villegas S, Emerson M, Turner D, Flesch AD, Deyo NS (2013) Biodiversity in the Madrean Archipelago of Sonora, Mexico. In: Gottfried GJ, Folliott PF, Bebow BS, Eskew LG (Eds) Merging Science and Management in a Rapidly Changing World: Biodiversity and Management of the Madrean Archipelago III. U.S. Department of Agriculture RMRS-P-67, 10–16.

Supplementary material 1

Figure S1

Authors: Ryan A. St Laurent, Lawrence E. Reeves, Akito Y. Kawahara

Data type: PDF figure

Explanation note: Maximum likelihood phylogenetic tree inferred with IQ-TREE based on the COI marker, rooted to *Gonogramma hanseni*.

Link: https://doi.org/10.3897/zookeys.931.50203.suppl1

Supplementary material 2

Table S1

Authors: Ryan A. St Laurent, Lawrence E. Reeves, Akito Y. Kawahara

Data type: Species data

Explanation note: Data for Cicinnini specimens used in this study, either sequenced *de novo* or extracted from publicly available data on BOLD (http://www.boldsystems.org/).

Link: https://doi.org/10.3897/zookeys.931.50203.suppl2

Supplementary material 3

File S1

Authors: Ryan A. St Laurent, Lawrence E. Reeves, Akito Y. Kawahara

Data type: Species data

Explanation note: Data and remarks for additional *Cicinnus* examined in this study.

Link: https://doi.org/10.3897/zookeys.931.50203.suppl3

Supplementary material 4

File S2

Authors: Ryan A. St Laurent, Lawrence E. Reeves, Akito Y. Kawahara

Data type: Genetic data

Explanation note: FASTA file of COI alignment for all taxa used in Figure 1/ Supplementary material 1.

Link: https://doi.org/10.3897/zookeys.931.50203.suppl4

Supplementary material 5

File S3

Authors: Ryan A. St Laurent, Lawrence E. Reeves, Akito Y. Kawahara

Data type: Phylogenetic data

Explanation note: Tree file in NEWICK format corresponding to phylogeny in Figure 1/ Supplementary material 1.

Link: https://doi.org/10.3897/zookeys.931.50203.suppl5

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RESEARCH ARTICLE

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Two new species of *Rhaphium* from Qinghai Province, China (Diptera, Dolichopodidae, Rhaphiinae)

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Abstract

At present, there are 31 species of *Rhaphium* Meigen recorded in China. In this paper, two species from Qinghai Province of China are described as new to science: *Rhaphium huzhuense* **sp. nov.**, *Rhaphium minhense* **sp. nov.** A key to the Chinese species of *Rhaphium* is provided.

Keywords

Long-legged fly, Palaearctic China, taxonomy, identification key

Introduction

The genus *Rhaphium* Meigen belongs to the subfamily Rhaphiinae and contains 206 known species in the world (Yang et al. 2006; Yang et al. 2011; Grichanov 2017; Qilemoge et al. 2019; Grootaert 2019). Thirty-one species have been recorded in China, including 11 species distributed only in Oriental China, 17 species distributed only in Palaearctic China, two species from Oriental and Palaearctic China, and one species, *R. dilatatum* Wiedemann, 1830, with an unclear Chinese distribution (Yang et al. 2006; Qilemoge et al. 2019; Grootaert 2019).

The specimens upon which this study is based were collected in the Qinghai Province of China. The Qinghai Province is located in the northeastern part of the Tibetan

Plateau in China, and has a continental climate. In this paper, we describe two new species of *Rhaphium* collected in this region. We provide an updated key to all Chinese species of *Rhaphium* with the exception of *R. dilatatum* and *R. relatus* (Becker, 1922), which are poorly described and lack known holotypes.

Material and methods

The specimens in this study were collected in the forest by sweep nets and subsequently stored into 95% ethanol, and finally stored in the freezer (-20 °C). All specimens are deposited in the Entomological Museum of China Agricultural University (CAU), Beijing. Morphological terminology for adult structures mainly follows Cumming and Wood (2017). The following abbreviations are used: **acr** = acrostichal bristle(s), **ad** = anterodorsal bristle(s), **av** = anteroventral bristle(s), **cer** = cercus, **CuAx ratio** = length of m-cu / length of distal portion of CuA, **dc** = dorsocentral bristle(s), **npl** = notopleural bristle(s), **oc** = ocellar bristle(s), **pal** = postalar bristle(s), **pprn** = postpronotal bristle(s), **pvt** = postvertical bristle(s), **ial** = intra-alar bristle(s), **sc** = scutellar bristle(s), **sur** = surstylus, **vt** = vertical bristle(s).

Taxonomy

Rhaphium Meigen, 1803

Diagnosis. Body size small to large (1.5–5.7 mm); vertex flat; ocellar bristle nearly as long as vertical bristle; face narrower than frons; male clypeus not clearly separate from face; antenna black, first flagellomere mostly prolonged (2–10 times longer than wide), arista apical; propleuron with dense pale white hairs, without distinct bristle; vein M not bifurcated, R_{4+5} parallel or slightly convergent with M apically, CuAx ratio less than 1; abdominal segments 1–3 usually with long pale hairs, abdominal segment 6 visible and pubescent; male genitalia connected tightly with pregenital segment, cap-like; epandrium wide apically, epandrial lobe generally simple with bristle; surstylus bifurcate or not; cercus varied, usually long and narrowed towards tip, sometimes bifurcate, with hairs and bristles at middle; hypandrium simple (Yang et al. 2011).

Key to species (males) of *Rhaphium* from China

1 First flagellomere at least 4.0 times longer than wide.................................. **2**
– First flagellomere at most 2.5 times longer than wide................................ **17**
2 Four dc... **3**
– Five to six dc.. **6**

3 First flagellomere less than 5.0 times longer than wide; acr present …………**4**

– First flagellomere more than 7.5 times longer than wide; acr absent…………………… ***R. sichuanense*** **Yang & Saigusa, 1999**

4 All coxae black; femora mostly black………… ***Rhaphium minhense*** **sp. nov.**

– At least fore coxa yellow, femora mostly yellow ……………………**5**

5 All coxae yellow ……………………***R. apicinigrum*** **Yang & Saigusa, 1999**

– Only fore coxa yellow ………………………… ***R. huzhuense*** **sp. nov.**

6 Arista apically inflated (Yang et al. 2011: fig. 809) …………………………… ***R. parentianum*** **Negrobov, 1979**

– Arista simple, not inflated at apex ……………………………**7**

7 Cercus bifurcate……………………………………………**8**

– Cercus not bifurcate……………………………………………**10**

8 First flagellomere at most 7.0 times longer than wide……………………**9**

– First flagellomere at least 9.0 times longer than wide………………………………… ***R. bilobum*** **Tang, Wang & Yang, 2016**

9 All coxae black……………… ***R. shaliuhense*** **Qilemoge, Wang & Yang, 2019**

– All coxae yellow ……………… ***R. daqinggouense*** **Tang, Wang & Yang, 2016**

10 First flagellomere at least 8.0 times longer than wide……………………**11**

– First flagellomere at most 6.0 times longer than wide……………………**12**

11 Eight uniseriate acr; cercus nearly triangular, short, not bifurcated…………………………… ***R. neimengense*** **Tang, Wang & Yang, 2016**

– Five to eight irregularly paired acr; cercus deeply bifurcated into 2 long lobes (Yang et al. 2011: fig. 816)………***R. zhongdianum*** **Yang & Saigusa, 2001a**

12 Surstylus bifurcate apically……………………………………**13**

– Surstylus simple……………………………………………**14**

13 Acr absent; all coxae yellow………………***R. furcatum*** **Yang & Saigusa, 2000**

– Acr present; fore coxa brown at base, mid and hind coxae brown with yellow apex ……………………***R. spinulatum*** **Grootaert, Taylor & Guénard, 2019**

14 Five dc; surstylus without apical incision………………………………**15**

– Six dc; surstylus with apical incision ……………………………**16**

15 Hind coxa yellow; surstylus thick, apically straight……………………………… ***R. palliaristatum*** **Yang & Saigusa, 2001b**

– Hind coxa brown with yellow apex; surstylus thin, apically rounded………………………… ***R. hongkongense*** **Grootaert, Taylor & Guénard, 2019**

16 All coxae yellow; hind tibia yellow; surstylus with long thick hairs apically; cercus long ribbon-like (Yang et al. 2011: fig. 815) …………………………… ***R. xinjiangense*** **Yang, 1998a**

– Only fore coxa yellow, mid and hind coxae black; hind tibia black; surstylus only with sparse short hairs; cercus elongate triangular (Yang et al. 2011: fig. 810)………………………………***R. qinghaiense*** **Yang, 1998b**

17 Fore tarsus modified (inflated, depressed or with Y-shaped bristle)…………**18**

– Fore tarsus simple ……………………………………………**23**

18 Fore tarsomere 1 simple, fore tarsomere 5 with 2 Y-shaped apical bristles and 2 long strong bristles .... ***R. dorsiseta*** **Tang, Wang & Yang, 2016**

– Fore tarsomere 1 modified **19**

19 Fore tarsomere 1 depressed dorsally but strongly raised ventrally .... ***R. lumbricus*** **Wei, 2006**

– Fore tarsomere 1 inflated apically **20**

20 Arista distinctly (1.4×) longer than first flagellomere **21**

– Arista nearly as long (0.8×) as first flagellomere (Yang et al. 2011: fig. 813) .... ***R. sinense*** **Negrobov, 1979**

21 Fore tarsomere 2, and mid tarsomeres 4 and 5 inflated (Yang et al. 2011: fig. 800) .... ***R. baihuashanum*** **Yang, 1998a**

– Fore and mid tarsi simple, not inflated **22**

22 Middle and lower postocular bristles yellow; 8 dc; mid femur yellow; cercus not bifurcate, narrowed toward apex .... ***R. heilongjiangense*** **Wang, Yang & Masunaga, 2005**

– All postocular bristles black; 5 dc; mid femur black; cercus bifurcate .... ***R. gangchanum*** **Qilemoge, Wang & Yang, 2019**

23 Fore femur with row of strong ventral bristles or long ventral hairs **24**

– Fore femur without row of distinct ventral bristles or hairs **25**

24 First flagellomere about 2.0 times as long as wide; arista about 2.0 times longer than first flagellomere; fore femur with row of long pale yellow ventral bristles as long as width of fore femur; cercus narrowed at base and widened towards apex, with distinct marginal denticles (Yang et al. 2011: fig. 811) .... ***R. riparium*** **(Meigen, 1824)**

– First flagellomere about 1.5 times as long as wide; arista nearly 3.0 times longer than first flagellomere; fore femur with 2 rows of long pale yellow bristles longer than width of fore femur; cercus very long, wide in basal half. .... ***R. apophysatum*** **Tang, Wang & Yang, 2016**

25 Fore tarsus modified, tarsomere 1 with row of strong ventral bristles on basal half, tarsomere 2 inflated apically (Yang et al. 2011: fig. 807c) **26**

– Fore tarsus simple, tarsomere 1 without distinct ventral bristles, tarsomere 2 simple **27**

26 Fore and mid femora yellow apically, fore and mid tibia yellow; fore coxa with black bristles and hairs .... ***R. micans*** **(Meigen, 1824)**

– Fore femur, mid and hind tarsi dark; fore coxa with light yellow bristles and hairs .... ***R. dispar*** **Coquillett, 1898**

27 All coxae dark, fore and mid femora yellow apically **28**

– Basal half of fore coxa and apical 1/3 of hind femur dark **29**

28 Hind tibia with 3 ventral bristles; mid tarsomere 1 about 1.1 times as long as hind tarsomere 1 .... ***R. wuduanum*** **Wang, Yang & Masunaga, 2005**

– Hind tibia without distinct ventral bristles; mid tarsomere 1 about 1.5 times as long as hind tarsomere 1 .... ***R. gansuanum*** **Yang, 1998a**

29 Mid coxa with 1 strong outer bristle, and bunch of ventral bristles; mid tibia with 1 av..**30**

– Mid coxa only with only 1 strong outer bristle at middle, without bunch of ventral bristles; mid tibia without ventral bristles ....***R. bisectum* Tang, Wang & Yang, 2016**

30 Calypteral fringe with yellow hairs; cercus not bifurcate; surstylus short and thick **31**

– Calypteral fringe with black hairs; cercus bifurcate; surstylus basally thick, apically sharp, with one protuberance ....***R. tianshuiense* Qilemoge, Wang & Yang, 2019**

31 First flagellomere less than 2.0 times as long as wide; fore femur entirely yellow.................................***R. canniccii* Grootaert, Taylor & Guénard, 2019**

– First flagellomere 2.0 times as long as wide; fore femur brownish except yellow at apex..**32**

32 Arista only slightly longer (1.2×) than first flagellomere ....***R. mediocre* (Becker, 1922)**

– Arista 3.0 times as long as first flagellomere...... ***R. eburnean* (Parent, 1926)**

***Rhaphium huzhuense* sp. nov.**
http://zoobank.org/4D9C6328-169D-4CD3-8450-B50C9C01EB35
Figs 1, 3, 4

Diagnosis. First flagellomere 7.5 times longer than wide. Fore coxa yellow, mid and hind coxae black except for yellow tip; hind femur black dorsally near apex; all tibiae yellow. CuAx ratio 0.35. Calypteral fringe with yellow hairs. Surstylus triangular, apically with four strong bristles. Cercus bifurcate, outer lobe long, slender, curved; inner lobe strip-like, apically with three strong bristles.

Description. Male (Fig. 1). ***Body*** length 3.6–3.75 mm. ***Wing*** length 4.0–4.2 mm.

Head metallic green with pale gray pruinescence. Face black with pale gray pruinescence. Frons brown with pale gray pruinescence. Upper postocular bristles black, middle and lower postocular bristles yellow. Two oc, two vt, two pvt. Antenna (Fig. 3) black; scape bare; pedicel with hairs; first flagellomere elongated, 7.5 times longer than wide, apically sharp; arista black, inserted at apex, basal aristomere 1/4 as long as apical aristomere. Proboscis and palpus black with yellow hairs.

Thorax metallic green with pale gray pruinescence. Hairs and bristles on thorax black. Four strong dc, four irregular pairs of acr, two strong npl, one strong sutural ial, two strong pa, one strong anterior pprn; scutellum with one pair of sc. Legs yellow, except for basal part of mid and hind coxae black; hind femur black dorsally near apex; fore and mid tarsi from tip of tarsomere 2 onwards black, tip of tarsomere 1 of fore and mid leg black, hind tarsus from tip of tarsomere 1 onward black. Most hairs and bristles on legs black, fore coxa with yellow bristles, and mid and hind coxae each

Figures 1, 2. Habitus, lateral view **1** *Rhaphium huzhuense* sp. nov., holotype male **2** *Rhaphium minhense* sp. nov., holotype male. Scale bars: 1 mm.

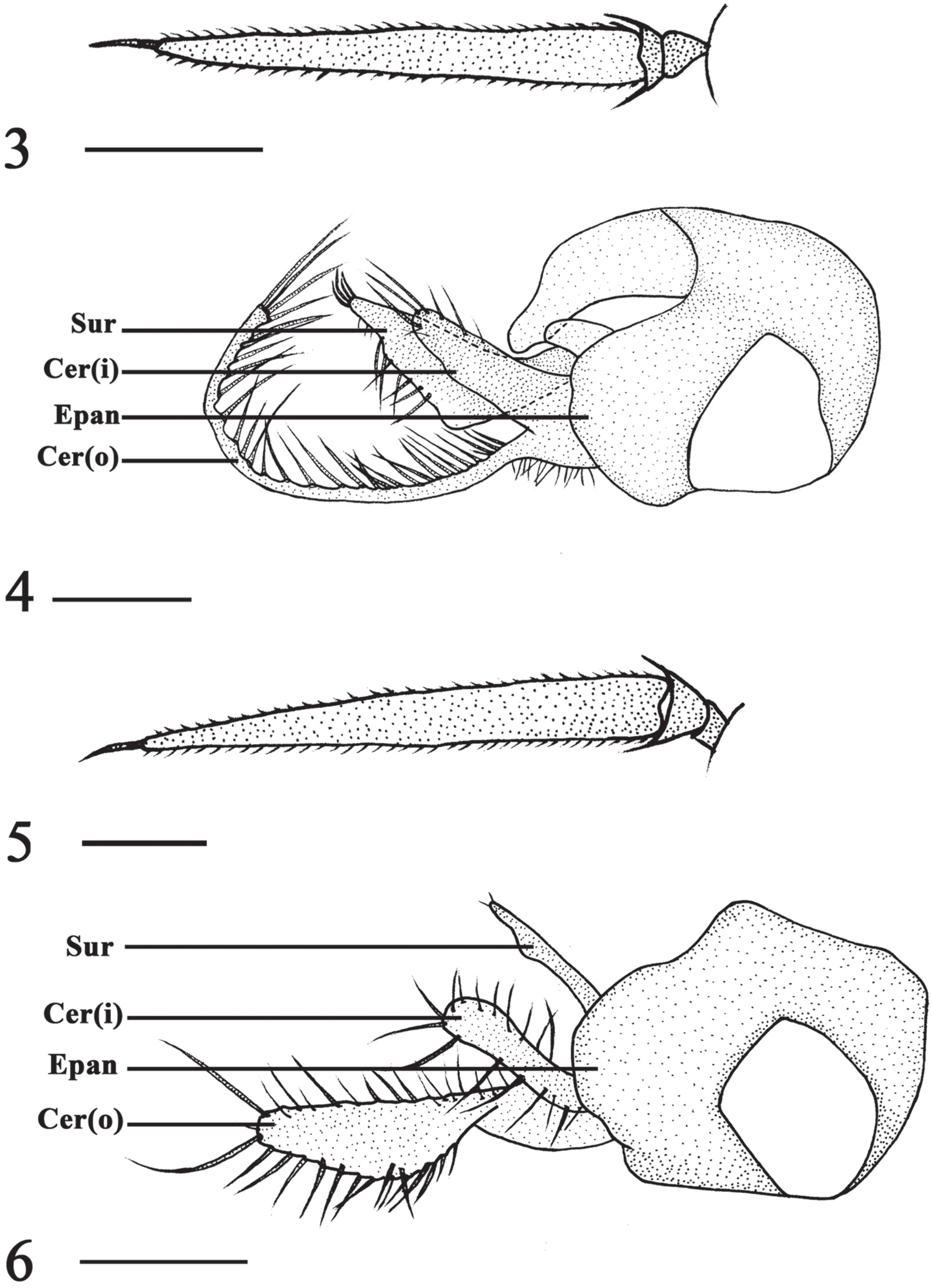
with one black outer bristle. All femora without ventral bristles, mid and hind femora each with one black preapical bristle. Fore tibia with one ad, two pv, middle with one av, and two apical bristles; mid tibia with two ad, one pd, basal half with one av, and three apical bristles; hind tibia with two ad, two pd, three av (basal half with one av, apical half with two av), and three apical bristles. Relative lengths of femur, tibia and 5 tarsomeres, fore leg 2.6 : 2.8 : 1.3 : 0.8 : 0.6 : 0.4 : 0.4; mid leg 4.0 : 4.3 : 1.9 : 1.2 : 0.8 : 0.6 : 0.4; hind leg 4.7 : 5.2 : 1.3 : 1.5 : 1.0 : 0.7 : 0.5. Wing hyaline, veins black; M bent medially, M and R_{4+5} parallel apically; CuAx ratio 0.35. Calypteral fringe yellow with yellow hairs. Halter yellow.

Abdomen metallic green with pale gray pruinescence with hairs and bristles black. Male genitalia (Fig. 4): epandrium black, nearly as long as wide. Epandrial lobe short, rounded apically, without distinct bristle. Surstylus on epandrium black, nearly triangular, outside margin with seven strong bristles and apex with four strong bristles. Cercus black, bifurcate, outer lobe long, slender, curved with strong bristles along length ventrally; inner lobe wider and shorter, strip-like, apically with three strong bristles.

Female. Unknown.

Types. ***Holotype*** male, China, Qinghai, Huzhu, Songduo Forest, 3165 m; 2019.VII.1, leg. Qilemoge (CAU), collected by sweep nets in grassland. ***Paratypes*:** two males, same data as holotype; six males, China, Qinghai, Minhe, Tangeryuan Forest, 2304 m, 2019.VI.28, leg. Xin Li (CAU), collected by sweep nets in grassland. (Figs 7, 8).

Distribution. Palaearctic: China (Qinghai).



Figures 3–6. *Rhaphium huzhuense* sp. nov., male **3** antenna, lateral view **4** genitalia, lateral view. *Rhaphium minhense* sp. nov., male **5** antenna, lateral view **6** genitalia, lateral view. Abbreviations: sur = surstylus, cer (o) = outer lobe of cercus, cer (i) = inner lobe of cercus, epan = epandrium. Scale bars: 0.2 mm.

Remarks. The new species is similar to *R. apicinigrum* Yang & Saigusa, 1999, but these two species can be separated by several features. In *R. huzhuense*, the first flagellomere is about 7.5 times longer than wide (Fig. 3); the fore coxa is yellow, the mid and hind coxae are black with the yellow apex; the hind femur is black apico-dorsally; and the surstylus is nearly triangular, not bifurcated (Fig. 4). In *R. apicinigrum*, the first flagellomere is about 4.3 times longer than wide; all coxae are yellow; and the surstylus is long and apically bifurcated (Yang et al. 2011: 1248, fig. 799a, b).

Etymology. The specific name refers to the type locality, Huzhu.

Rhaphium minhense **sp. nov.**

http://zoobank.org/B8FD1531-B5DD-4D83-AE5A-64B47886FD90
Figs 2, 5, 6

Diagnosis. First flagellomere 6.5 times longer than wide. Legs mostly black except fore and mid femora ventrally yellow at tip and hind femur ventrally yellow on basal 3/4. CuAx ratio 0.36. Calypteral fringe with black hairs. Surstylus finger-like, ventrally with one protuberance. Cercus bifurcate, outer lobe twisted at middle, apical half nearly triangular; inner lobe strip-like with strong bristles.

Description. Male (Fig. 2). ***Body*** length 4.0 mm. ***Wing*** length 4.6 mm.

Head metallic green with pale gray pruinescence. Face dark metallic green with silvery white pruinescence. Frons brown with pale gray pruinescence. Upper postocular bristles black, middle and lower postocular bristles yellow. Two oc, two vt, two pvt. Antenna (Fig. 5) black; scape bare; pedicel with hairs; first flagellomere elongated, 6.5 times longer than wide, with acute apex; arista black, inserted at apex, basal aristomere 1/4 as long as apical aristomere. Proboscis black with yellow hairs, palpus black with black hairs.

Thorax metallic green with pale gray pruinescence. Hairs and bristles on thorax black. Four strong dc, four irregular pairs of acr, two strong npl, one strong sutural ial, two strong pa, one strong anterior pprn; scutellum with one pair of sc. Legs black, except for fore and mid femora ventrally yellow at tip, hind femur ventrally yellow at basal 3/4. Most hairs and bristles on legs black. Fore and mid coxae with yellow bristles, hind coxa with one black outer bristle. Mid and hind femora each with one black preapical bristle. Fore tibia with one ad, one pd, basal half with two av, and two apical bristles; mid tibia with two ad, one pd, apical half with one av, and four apical bristles; hind tibia with two ad, two pd, three av (middle with one av, apical half with two av), and four apical bristles. Relative lengths of femur, tibia and 5 tarsomeres, fore leg 2.4 : 2.5 : 1.2 : 0.5 : 0.4 : 0.2 : 0.3; mid leg 3.1 : 3.0 : 1.6 : 0.7 : 0.5 : 0.4 : 0.4; hind leg 3.5 : 3.9 : 1.6 : 1.6 : 0.8 : 0.5 : 0.4. Wing hyaline, veins black; M bent medially, M and R_{4+5} parallel apically; CuAx ratio 0.36. Calypteral fringe yellow with black hairs. Halter yellow.

Abdomen metallic green with pale gray pruinescence with hairs and bristles black. Male genitalia (Fig. 6): epandrium black, nearly as long as wide. Surstylus on epan-

Figures 7, 8. Habitat **7** Qinghai, Minhe, Tangeryuan Forest **8** Qinghai, Huzhu, Songduo Forest.

drium black, thin, finger-like, apically sharp, with two weak bristles, ventrally with one protuberance. Cercus bifurcate, outer lobe thick, twisted at middle, nearly triangular at apical half, apically with two long strong bristles; inner lobe strip-like, apically rounded, with three strong bristles, ventrally with five long strong bristles.

Female. Unknown.

Types. ***Holotype*** male, China, Qinghai, Minhe, Tangeryuan Forest, 2304 m, collected by sweep nets in grassland, 2019.VI.28, leg. Xin Li (CAU) (Fig. 8).

Distribution. Palaearctic: China (Qinghai).

Remarks. The new species is similar to *R. shaliuhense* Qilemoge et al., 2019, but both species can be separated by several features. In *R. minhense*, the body length is 4.0 mm; the thorax has four strong dc; the fore and mid femora are yellow ventrally at tip; the Calypteral fringe has black hairs; the outer lobe of cercus is twisted at middle, the apical half part is nearly triangular (Fig. 6). In *R. shaliuhense*, the body length is 2.5 mm; the thorax has five strong dc; the fore and mid femora are black; the Calypteral fringe has yellow hairs; the outer lobe of the cercus is strip-like (Qilemoge et al. 2019: 94, fig. 7).

Etymology. The specific name refers to the type locality, Minhe.

Discussion

Rhaphium is the largest genus in Rhaphiinae and including the species described here there are now 33 species documented to occur in China. Several species groups have been proposed within *Rhaphium*, for example Negrobov (1986) proposed a key to Palaearctic and Nearctic species of the *R. nasutum* group, having the following characters: hind coxa with a group of lateral hairs, fore tarsomere 1 with a row of short black bristles, cercus divided into lobes. Grichanov (2004) and Naglis (2009) mentioned the *R. albifrons* group, with the following combination of characters: hind coxa with a strong white lateral bristle; fore tarsomere 1 without comb of strong bristles; a key to males was provided. Negrobov and Grichanov (2010) described, and provided a key to, the

R. crassipes group, diagnosed by: mid tarsomeres 4–5 black, dilated and flattened dorsoventrally. Naglis and Grootaert (2011) published the *R. srilankensis* group, with the sole nominal species notable for the arista being absent in males, and provided a key to Oriental genera of Rhaphiinae. Negrobov et al. (2011) proposed the *R. tridactylum* group, included four species, and provided a key to species. Negrobov et al. (2013) described the *R. ensicorne* group in which the cercus is bifoliate. Tang et al. (2016) mentioned the *R. bilobum* group with the defining characters: thorax with 5 dc; cercus bifurcate with two simple lobes and the *R. flavilabre* group, diagnosed by: thorax with 5 dc; male genitalia shorter than epandrium, with long pale apical bristles which are at least as long as epandrium. Grootaert et al. (2019) proposed the *R. micans* group, which differed by the following characters: cercus long, flattened, nearly twice as long as epandrium. The two new species described here do not fit the diagnoses of any of the above species groups.

Previously, there were 31 species recorded from China. Here we report two new species of *Rhaphium* from the Qinghai Province of Palaearctic China. *Rhaphium* can be considered a widespread genus in China. However, Ningxia, Xinjiang and Shanxi have few species, which might be due to the relatively dry climates of these provinces. The sole species (*R. heilongjiangense*) was known from the northeastern provinces (Heilongjiang, Jilin, Liaoning) of China: inadequate collection might be another reason for lower species diversity (Yang et al. 2011).

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References

Becker T (1922) Dipterologische Studien, Dolichopodidae der indo-australischen Region. Capita Zoologica 1(4): 1–247. https://doi.org/10.5962/bhl.title.132893

Cumming JM, Wood DM (2017) Adult Morphology and Terminology. In: Kirk-Spriggs AH, Sinclair BJ (Eds) Manual of Afrotropical Diptera (Vol. 1). South Africa National Biodiversity Institute, Pretoria, 89–133.

Grichanov IY (2004) A list of Dolichopodidae from the Tyresta National Park, Sweden, with description of a new species of the genus *Rhaphium* Meigen (Diptera). Zoosystematica Rossica 12(2): 267–269.

Grichanov IY (2017) Alphabetic list of generic and specific names of predatory flies of the epifamily Dolichopodidae (Diptera) (2nd ed.). Plant Protection News Supplements 23: 442–455.

Grootaert P, Taylor C, Guénard B (2019) Three new species of *Rhaphium* Meigen, 1803 from mangroves in Hong Kong (Diptera: Dolichopodidae: Rhaphiinae). European Journal of Taxonomy 540: 1–21. https://doi.org/10.5852/ejt.2019.540

Naglis S (2009) Some taxonomical changes in the genus *Rhaphium* (Diptera, Dolichopodidae), with a key to the *Rhaphium albifrons* species group. Mitteilungen der Schweizerischen Entomologischen Gesellschaft 82: 201–203. https://doi.org/10.11646/zootaxa.2991.1.6

Naglis S, Grootaert P (2011) A remarkable new species of *Rhaphium* Meigen (Diptera, Dolichopodidae) from Sri Lanka. Zootaxa 2991: 44–48.

Negrobov OP (1979) Dolichopodidae. In: Lindner E (Ed.) Die Fliegen der Palaearktischen Region 4(5). Lieferung 322: 475–530.

Negrobov OP (1986) Holarctic links in family Dolichopodidae. Biogeografiya Beringiiskogo sektora Subarktiki: Materialy Vsesoyuz, Simpoz, Magadan 1983: 161–168.

Negrobov OP, Barkalov AV, Selivanova OB (2011) New dolichopodid species of the genera *Dolichopus Latreille*, 1797 and *Rhaphium Meigen*, 1803 (Diptera, Dolichopodidae) from Siberia. Euroasian Entomological Journal 10(2): 203–206.

Negrobov OP, Grichanov IY (2010) The *Rhaphium crassipes* species group in the Palearctic Region with the description of a new species from Uzbekistan (Diptera: Dolichopodidae). Caucasian Entomological Bulletin 6(1): 117–122. https://doi.org/10.23885/1814-3326-2010-6-1-117-122

Negrobov OP, Grichanov IY, Selivanova OV (2013) Palearctic species of the *Rhaphium albifrons* group (Diptera, Dolichopodidae). Euroasian Entomological Journal 12(6): 601–606.

Parent O (1926) Dolichopodidés nouveaux de l'extrême orient paléarctique. Encyclopédie entomologique. Serie B. II. Diptera (Vol. 3). Paris, 111–149.

Qilemoge, Wang MQ, Yang D (2019) Three new species of *Rhaphium* from China, with an updated key to Chinese *Rhaphium* (Diptera, Dolichopodidae, Rhaphiinae). Zookeys 840: 84–99. https://doi.org/10.3897/zookeys.840.31602

Tang CF, Wang N, Yang D (2016) *Rhaphium* (Diptera: Dolichopodidae: Rhaphiinae) from China with six new species. Zootaxa 4162(3): 581–593. https://doi.org/10.11646/zootaxa.4162.3.11

Wang MQ, Yang D, Masunaga K (2005) Notes on *Rhaphium* Meigen from the Chinese mainland (Dilichopodidae, Diptera). Transactions of the American Entomological Society 131: 403–409.

Wei L (2006) Dolichopodidae. In: Li Z, Jin D (Eds) Insects from Fanjingshan Landscape. Guizhou Science and Technology Publishing House, Guiyang, 468–502.

Yang D (1998a) New and little known species of Dolichopodidae from China (I). Bulletin de l' Institute Royal des Sciences Naturelles de Belgique, Entomologie 68: 151–164.

Yang D (1998b) New and little known species of Dolichopodidae from China (III). Bulletin de l' Institute Royal des Sciences Naturelles de Belgique, Entomologie 68: 177–183.

Yang D, Saigusa T (2001) New and little known species of Dolichopodidae (Diptera) from China (IX). Bulletin de l'Institut Royal des Sciences Naturelles de Belgique Entomologie 71, 165–188.

Yang D, Saigusa T (1999) New and little known species of Dolichopodidae from China (VI). Bulletin de l' Institute Royal des Sciences Naturelles de Belgique, Entomologie 69: 233–250.

Yang D, Saigusa T (2000) New and little known species of Dolichopodidae from China (VII): Diptera from Emei Mountain (2). Bulletin de l' Institute Royal des Sciences Naturelles de Belgique, Entomologie 70: 219–242.

Yang D, Saigusa T (2001a) New and little known species of Dolichopodidae (Diptera) from China (IX). Bulletin de l' Institute Royal des Sciences Naturelles de Belgique, Entomologie 71: 165–188.

Yang D, Saigusa T (2001b) New and little known species of Dolichopodidae (Diptera) from China (XI). Bulletin de l' Institute Royal des Sciences Naturelles de Belgique, Entomologie 71: 237–256.

Yang D, Zhang LL, Wang MQ, Zhu YJ (2011) Fauna Sinica Insecta (Vol. 53). Diptera Dolichopodidae. Science Press, Beijing, 1241–1273.

Yang D, Zhu YJ, Wang MQ, Zhang LL (2006) World catalog of Dolichopodidae (Insecta: Diptera). China Agricultural University Press, Beijing, 340–357.

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CHECKLIST

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A checklist of the amphibians and reptiles of Sinaloa, Mexico with a conservation status summary and comparisons with neighboring states

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Abstract

Sinaloa possesses a rich biota with unique characteristics due to its proximity to the northern deserts, the tropical lowlands of the south, and the temperate environments of the western slopes of the Sierra Madre Occidental in Mexico. However, threats to its environment makes understanding the biological diversity of Sinaloa crucial. A checklist of the amphibians and reptiles has been generated, and the conservation status of Sinaloa's herpetofauna summarized with the aim of understanding the potential conservation or management needs. Sinaloa has 159 species of amphibians and reptiles, including 39 species of amphibians and 120 species of reptiles. The herpetofauna of Sinaloa has relatively few species of conservation concern at a global and national scale (IUCN and SEMARNAT lists), but Environmental Vulnerability Scores suggest that there might be greater conservation concerns for the Sinaloa herpetofauna. Families of particular conservation concern include Craugastoridae, Eleutherodactylidae, Ambystomatidae, Crocodylidae, Dactyloidae, Eublepharidae, Helodermatidae, Iguanidae, Phrynosomatidae, Phyllodactylidae, Colubridae, Natricidae, Viperidae, Cheloniidae, and Dermochelyidae.

Keywords

checklist, crocodilians, frogs, herpetofauna, lizards, salamanders, snakes, turtles

Introduction

The geographic position of Sinaloa (Fig. 1) results in a rich biota with unique characteristics which is composed of a mixture of species from the northern deserts, the tropical lowlands of the south, and the temperate environments of the western slopes of the Sierra Madre Occidental (see Bezy et al. 2017 for herpetofauna). Unfortunately, Sinaloa's biological diversity is currently at risk. The growing human population of Sinaloa, which demands more and more resources, has created a large number of open landfills and increased air and water pollution from the use of unsustainable practices without any regard for and enforcement of environmental legislation (Beltrán 2017). Deforestation in Sinaloa has been particularly devastating as more than 50% of its surface area has been cleared to create cultivated areas, so that natural vegetation is now limited to isolated areas with limited access (INEGI 2017). Mangrove wetlands in Sinaloa are also being lost due to human activities (Manzano-Sarabia et al. 2018). In addition, there are numerous, more specific, threats to the herpetofauna of Sinaloa. These threats include the potential spread of emerging diseases of amphibians and reptiles (Mejia-Radillo et al. 2019; Saucedo et al. 2019), lowering or disruption of freshwater aquifers due to agricultural or residential use (Quinones et al. 1999; Torres-Sombra et al. 2013), heavy metal pollution from mining activities (Muñoz Sevilla et al. 2017), loss of natural land cover due to agricultural expansion (Ruíz-Luna and Berlanga-Robles 1999). This environmental degradation and increasing environmental threats make understanding the biological diversity of Sinaloa crucial. To that end, we contribute to the knowledge of the herpetofauna of Sinaloa by placing a checklist of the amphibians and reptiles in an easily accessible place. A previous checklist by Hardy and McDiarmid (1969) reported 131 species: 32 anurans, 33 lizards, 55 snakes, and ten turtles, and pointed out that the list might increase if access to the eastern mountains was improved. However, in recent years, there has been a paucity of studies on the herpetofauna of Sinaloa, in part due to the lack of security that prevails in the eastern part of the state where illegal crops are common, and to the lack of roads allowing access. We hope an updated checklist will provide a starting place for further research on the herpetofauna of Sinaloa. In addition, we summarize the conservation status of Sinaloa's herpetofauna and compare the lists of amphibian and reptile species to those in neighboring states to identify unique aspects of the herpetofauna of Sinaloa, as well as shared species, with the aim of understanding the potential conservation or management needs at the state or regional level.

Physiographic characteristics of the state

The relatively small state of Sinaloa (surface area of 58,328 km^2) is located in northwestern Mexico, between 27°2'32" and 22°28'2"N and 105°23'32" and 109°26'52"W (Figs 1, 2; INEGI 2017). Sinaloa is bordered by Sonora to the north, Chihuahua and Durango to the east, Nayarit to the south, and the Gulf of California to the west.

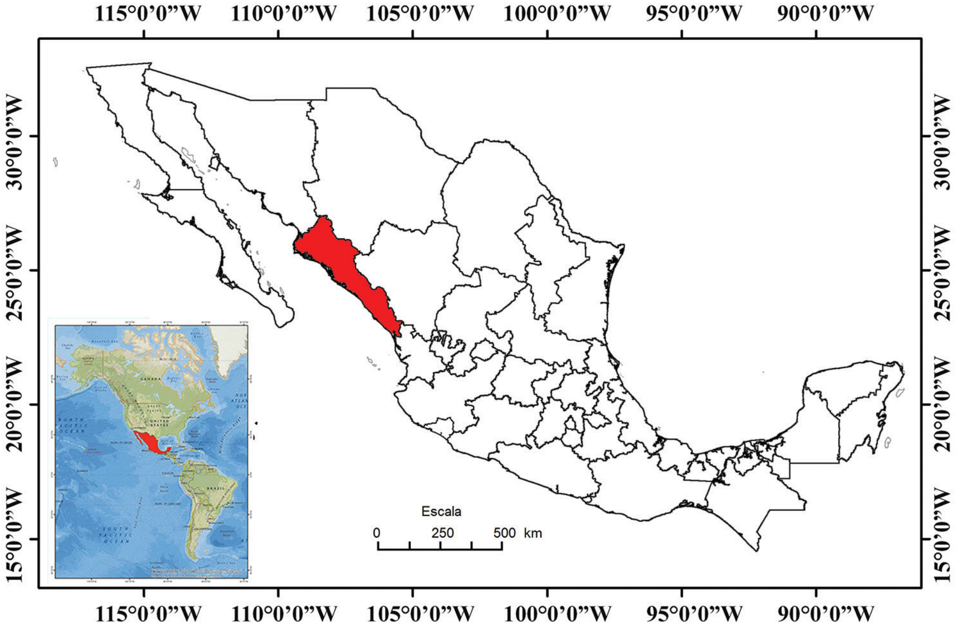

Figure 1. Map of Mexico with the state of Sinaloa shown in red (modified from INEGI 2018a).

The topography of Sinaloa can be divided into three large longitudinal strips (INEGI 2017). The first includes the mountain ranges of the Sierra Madre Occidental on the eastern side of the state. In Sinaloa, elevations rarely exceed 2,500 m, with the highest elevations near the border with Chihuahua (Cerro La Bandera: 2,280 m and Cerro Pelón: 2,500 m) and Durango (Cerro Alto: 2,800 m; Cerro Narizón: 2,560 m; and Cordón El Copo Alto: 2,360 m). The second strip is an extensive plain that lies between the foothills of the Sierra Madre Occidental and the Pacific Coast, which is the third strip. In northern Sinaloa the distance between the foothills of the Sierra Madre Occidental and the coast of the Pacific Ocean is greater than in southern Sinaloa, where they can be separated by less than 30 km. Throughout the state, the Pacific coastline is interrupted by large lagoons and mangroves, and although the coastline is straight and low, except for Mazatlán Bay, access to it is difficult due to the presence of these lagoons (Fig. 2; García-Martínez 2008; INEGI 2017).

Sinaloa includes two physiographic provinces: Sierra Madre Occidental and Llanura Costera del Pacífico. The Sierra Madre Occidental covers 59.5% of Sinaloa, covering a little more than the eastern half of the state (Fig. 3; INEGI 2017). The Llanura Costera del Pacífico covers 40.5% of the state, including almost all of the western half of the state (Fig. 3; INEGI 2017).

The elongated shape of Sinaloa along with its topography characterized by a continuous mountain chain in the east running parallel to the coastline, produces a striped distribution of vegetation types in the state (Fig. 4). The flood plains of

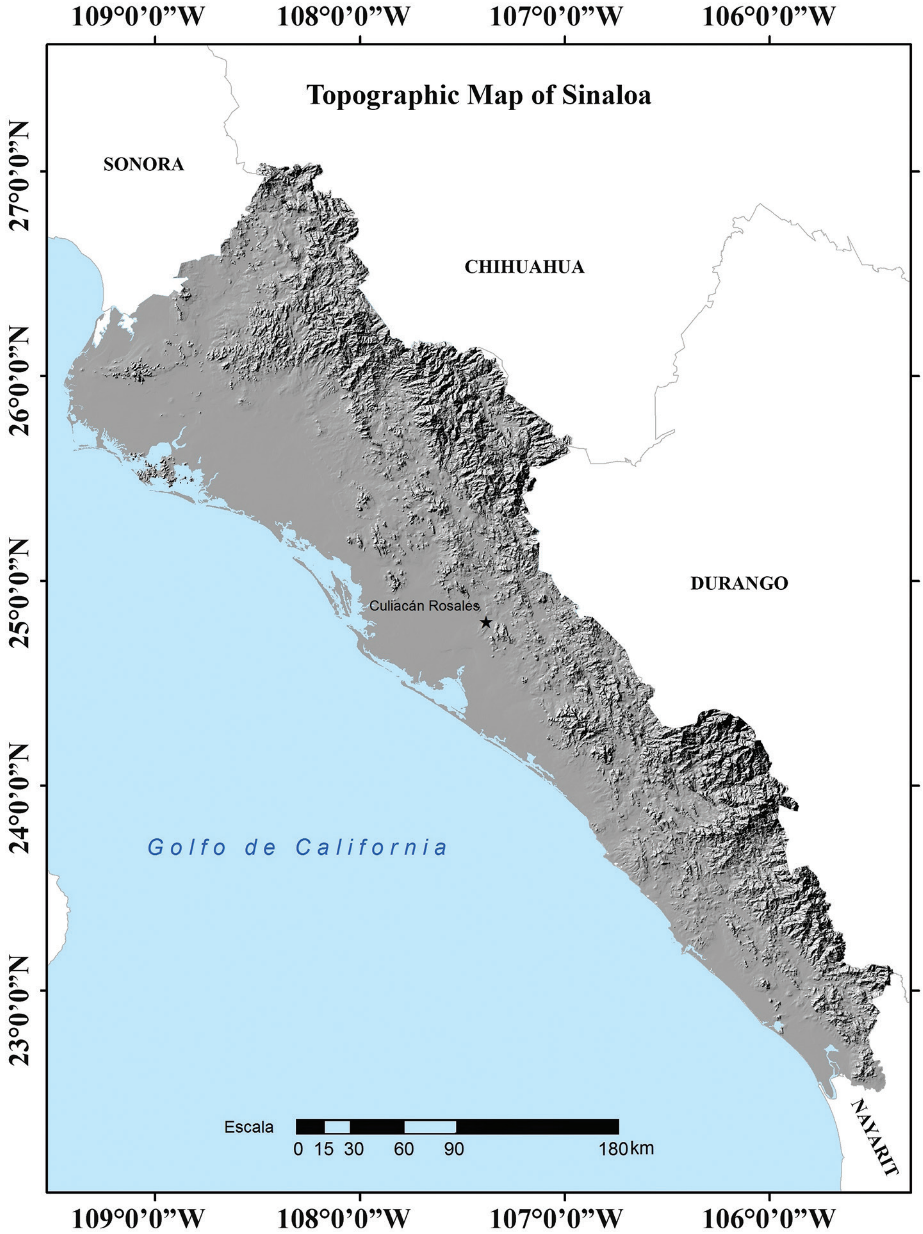

Figure 2. Topographical map of the state of Sinaloa, Mexico (INEGI 2009).

the main Sinaloa rivers and adjacent upland slopes have been cleared and cultivated for many centuries, such that the natural plant associations have been considerably altered, and the actual Sinaloa landscape has large areas with an unnaturally high percentage of commercially worthless trees and shrubs, and commercial crops such

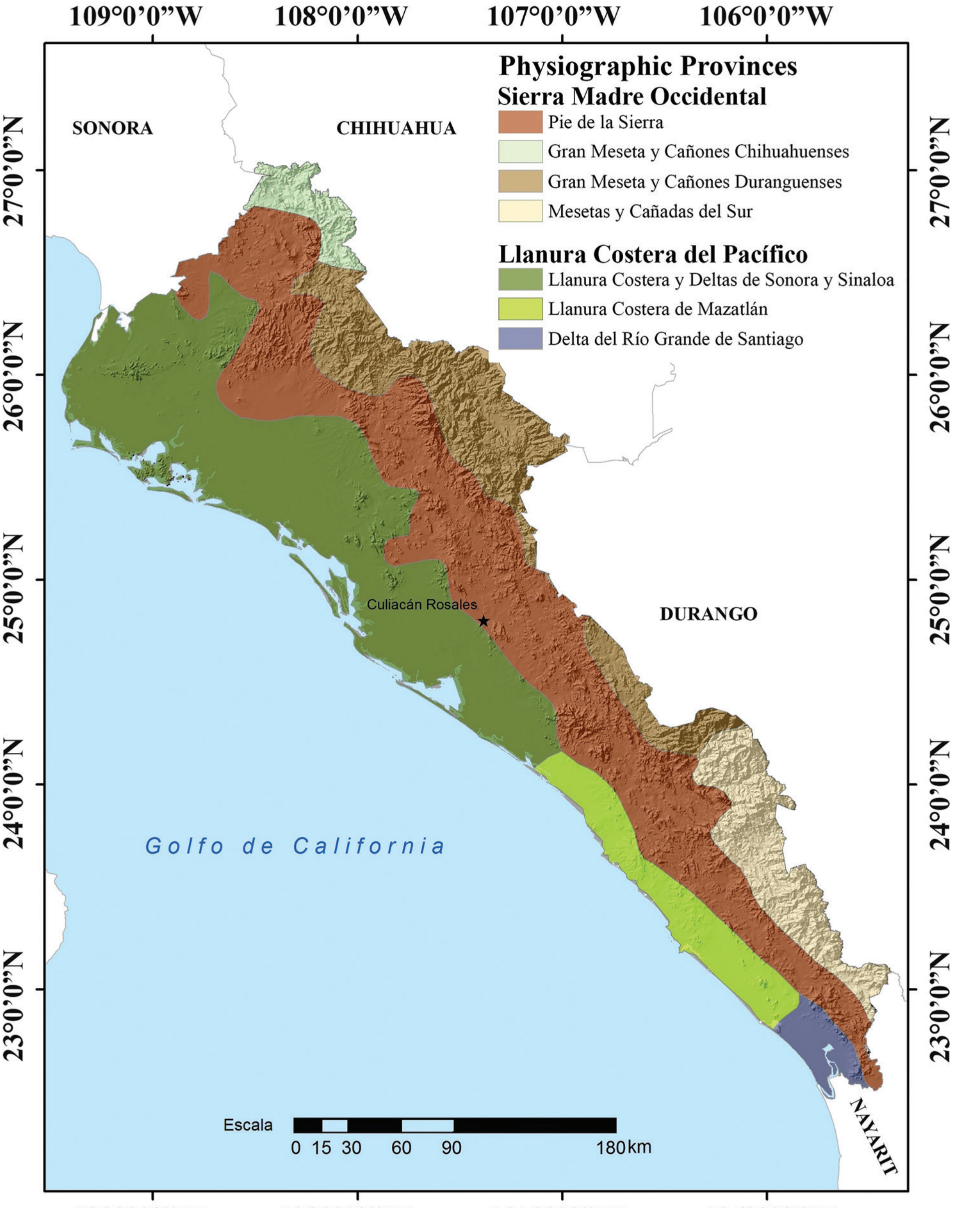

Figure 3. Physiographic provinces of the state of Sinaloa, Mexico (modified from Cervantes-Zamora et al. 1990).

as corn, sorghum, tomatoes, mango, and sugarcane. The natural vegetation has been replaced by large areas of cultivation (Fig. 4), which also house numerous human populations ranging from small ejidos to large cities (Brand 1936; INEGI 2017). The dominant natural vegetation is tropical deciduous forest found along the western

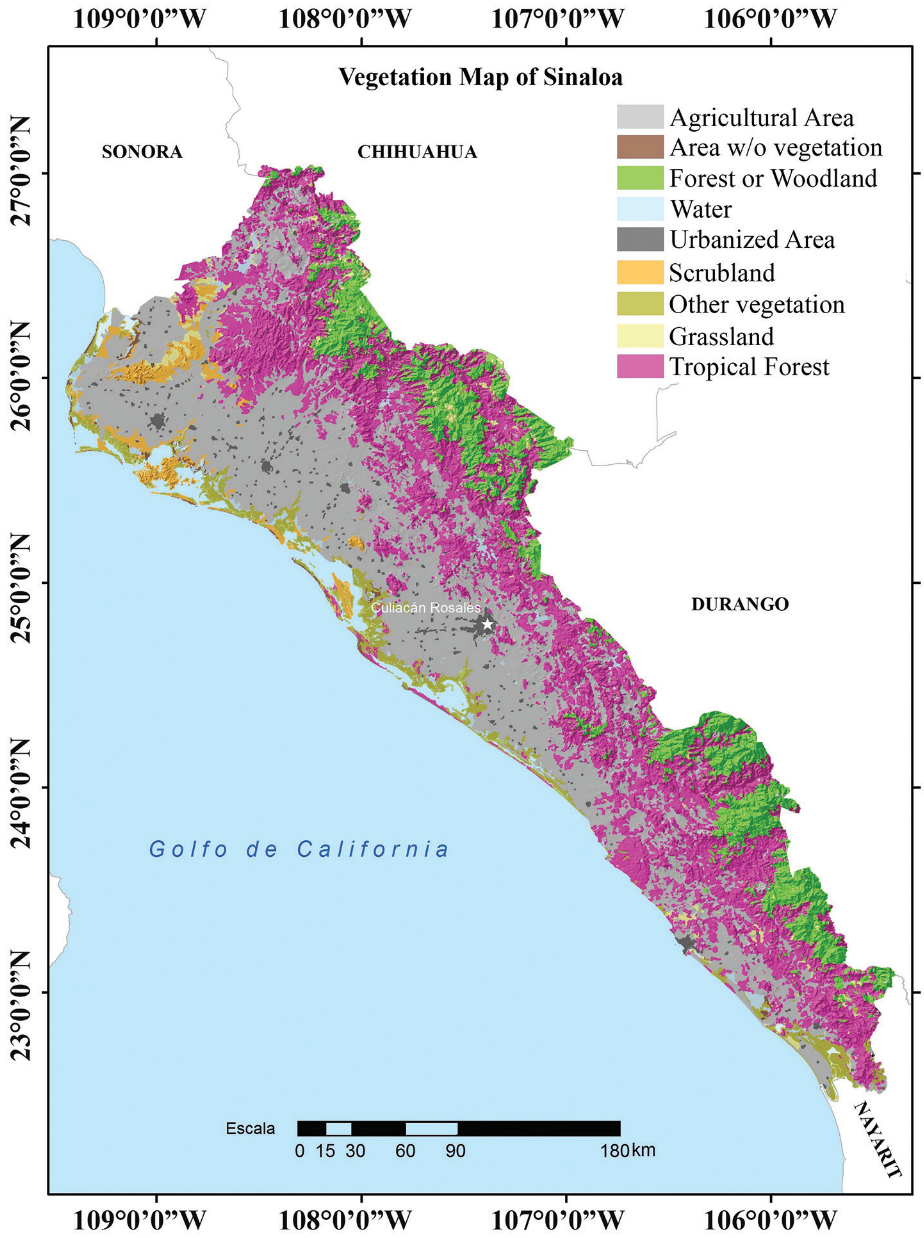

Figure 4. Vegetation map of the state of Sinaloa, Mexico (modified from Dirección General de Geografía – INEGI 2013).

slopes of the Sierra Madre Occidental of Sinaloa. Tropical deciduous forest in southern Sinaloa is separated from the upland oak woodland and pine-oak forest by semi-deciduous tropical forest, a much more tropical vegetation type (Ruíz-Guerrero et al. 2015). The density of this forest is higher in the southern third of Sinaloa and is more open in the northeastern part of the state. In addition, southern Sinaloa has the huge Marisas Nacionales wetlands that abut semi-deciduous forest (T. Van Devender, pers. comm.). Tree species in the southern third are also taller than those in the northern part of the state. This vegetation type is found from the southern third of the state along the foothills of the Sierra Madre Occidental to the northeastern corner of the state. On the highest mountains of the Sierra Madre Occidental, the vegetation often changes to oak and pine-oak forest along the borders with Durango and Chihuahua (INEGI 2017). The coastal plain of the northern half of Sinaloa shows great uniformity in vegetation, gradually changing as one moves to the south (INEGI 2017). The belt immediately along the coast is more arid than the interior and its vegetation is poorer and more open. The flood plains are largely devoted to vast cultivated fields of sugar, garbanzo, tomatoes, and corn. The natural vegetation is more luxuriant than that of the uplands and includes many tropical plants. The vegetation of the hills, which are scattered over the plain, is commonly very similar to that of the plain. In the lowlands of Sinaloa, the coastal plain type of "thorn forest", a mixture of tropical deciduous forest and thornscrub, predominates in area over the vegetation characterizing the flood plains, the coast, and the hills (Shreve 1937). The vegetation along the coast of Sinaloa north of Mazatlán is a vegetation type that could be considered short tropical deciduous forest (T. Van Devender, pers. comm.). In the northwestern corner of the state near Sonora, the vegetation type is subtropical Mimosaceae-cacti characterized by spiny shrubs and cacti dominated by Mimosaceae and columnar cacti. This vegetation is not distributed uniformly, rather it is arranged in clumps, but with a nearly continuous cover in wetter spots (Brand 1936). In Sonora, thorn scrub is a transitional vegetation type between tropical deciduous forest and the Sonoran Desert to the north and the woodlands and forests of the Sierra Madre Occidental to the east (Martin et al. 1998; Van Devender et al. 2013).

In Sinaloa there is a trend for precipitation to decrease from southern to northern Sinaloa. The dominant climate in Sinaloa is warm semi-warm sub-humid which covers 48.4% of the state and is present from the southern tip of the state to the Port of Mazatlán, and from there in a narrow strip along the foothills of the western slopes of the Sierra Madre Occidental of Sinaloa, along the borders with Durango and Chihuahua. This area is characterized by a mean annual temperature over 18 °C. Precipitation of the driest month is < 40 mm. Small scattered locations in the highest mountains of the extreme southeastern and northeastern parts of Sinaloa are characterized by a temperate sub-humid climate, present in only 2.3% of the state. The climate of these elevated peaks is characterized by an average annual temperature between 12 °C and 18 °C. Rainfall in the driest month is < 40 mm; the maximum rainfall occurs in summer. A narrow strip that runs parallel to the foothills of the Sierra Madre Occidental, covering 21.3% of the state surface area, from just north of the Port of Mazatlán to the border with Sonora in northern Sinaloa is characterized by a semiarid climate with a mean annual temperature > 22 °C. Parallel to this strip and next to the coastline the climate is arid, with an average annual temperature > 22 °C. The extreme northwestern corner of the state, from the border with Sonora to just south of the Port of

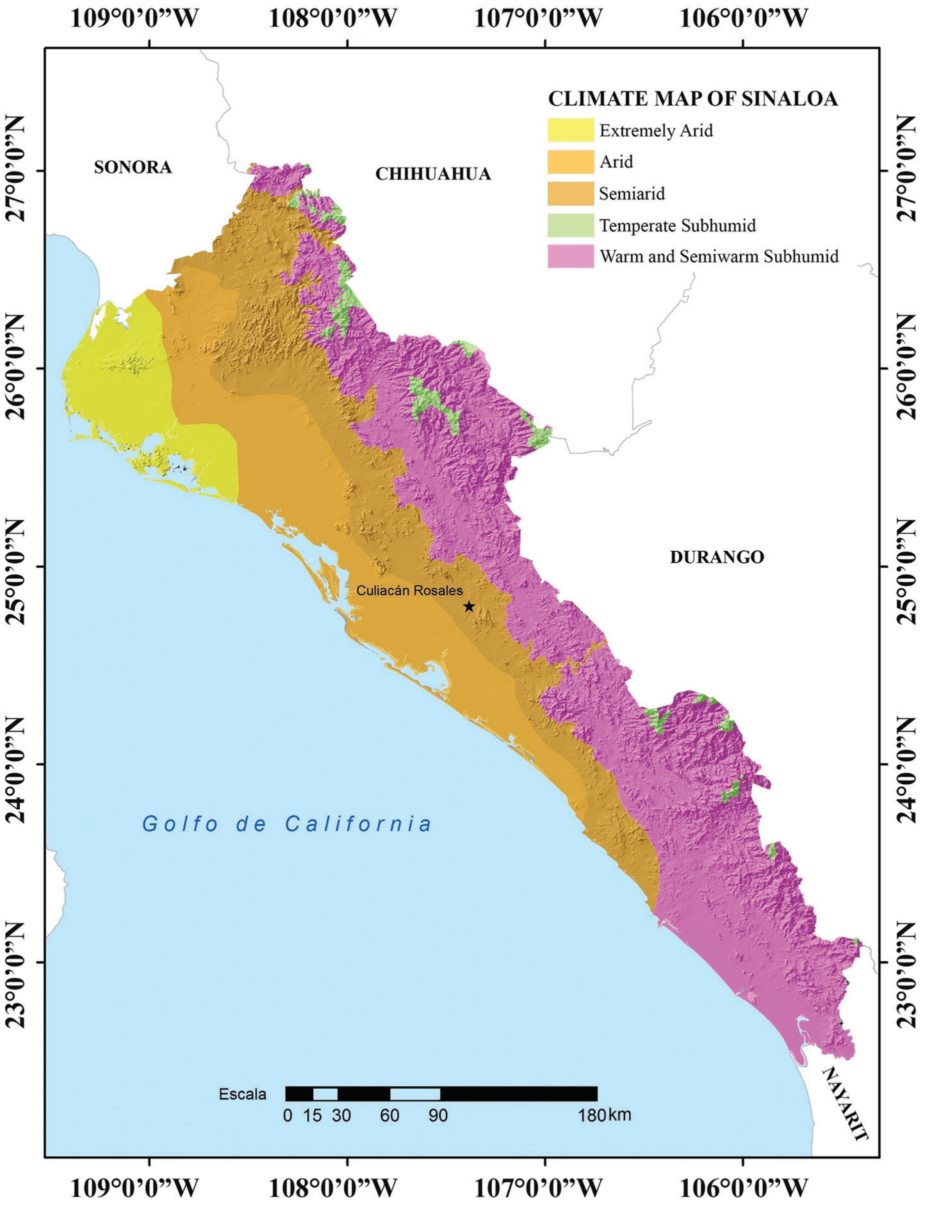

Figure 5. Climate map of the state of Sinaloa, Mexico (modified from García – Comisión Nacional para el Conocimiento y Uso de la Biodiversidad 1998).

Topolobampo, which covers 9.8% of the state surface territory, is characterized by an extreme arid climate with an average annual temperature above 22 °C, and eight continuous months of dry to very dry conditions. Heavy rains occur in the July-September, which represent more than 75% of the annual total (Fig. 5; Köppen modified by García 1998; INEGI 2017).

Materials and methods

We compiled this list of amphibians and reptiles of Sinaloa based on our field work, a thorough examination of the available literature on amphibians and reptiles in Sinaloa, and records of amphibians and reptiles from Sinaloa in VertNet.org. We only included species if we were able to confirm records, either by direct observation or through documented museum records or vouchers. We follow Frost (2019) and AmphibiaWeb (2019) (http://amphibiaweb.org) for amphibian names and Uetz and Hošek (2019) for reptile names. We generated species accumulation curves the total herpetofauna, amphibians, and reptiles using the year of the first recorded observation for each species. Such curves reasonably estimate potential species richness of amphibians and reptiles (Raxworthy et al. 2012). We determined the conservation status of each species from the IUCN Red List 2019-2 (IUCN 2019), SEMARNAT (2010), and Environmental Vulnerability Scores (Wilson et al. 2013a, b; Johnson et al. 2015). We determined the number of species found in Sinaloa that were shared with the four neighboring states using recent herpetofaunal check lists for Sonora (Lemos-Espinal et al., 2019a), Chihuahua (Lemos-Espinal et al. 2017), Durango (Lemos-Espinal et al. 2019b), and Nayarit (Woolrich-Piña et al. 2016). We also included the Baja California Peninsula in this comparison, using Grismer (2002) and Hollingsworth et al. (2015) as species lists, since it used to be contiguous with the states of Sinaloa and Sonora. To avoid overestimation of the shared species in this region we excluded species occurring only on Islands Tiburón and San Esteban, since those are included in the Sonora Checklist but not the Peninsula proper.

Results and discussion

Sinaloa is home to 159 species of amphibians and reptiles representing 35 families (including two introduced: Gekkonidae and Typhlopidae) and 89 genera (including three introduced: *Gehyra*, *Hemidactylus*, and *Indotyphlops*) (Table 1). There are 39 species of amphibians (38 anurans [one introduced], and one salamander) and 120 reptiles (one crocodilian, 42 lizards [two introduced], 64 snakes [one introduced], and 13 turtles). The four introduced species are: the American Bullfrog (*Rana catesbeiana*), the Stump-toed Gecko (*Gehyra mutilata*), the Common House Gecko (*Hemidactylus frenatus*), and the Brahminy Blindsnake (*Indotyphlops braminus*). *Anolis utowanae* is the only species endemic to Sinaloa and is only known from the type specimen. There are six marine species that occur along the coast of Sinaloa (*Hydrophis platurus*, *Caretta caretta*, *Chelonia mydas*, *Eretmochelys imbricata*, *Lepidochelys olivacea*, and *Dermochelys coriacea*).

We suggest that there are 19 species (seven amphibians, 12 reptiles) that potentially occur in Sinaloa but that have not yet been documented in the state (Table 2). Eighteen of these species are found in Durango and Chihuahua near the border with eastern and northeastern Sinaloa, and one species is found in Nayarit near the border with southern Sinaloa. Distributional records reported in Lemos-Espinal and Smith (2007: Chihuahua), and Lemos-Espinal et al. (2019a: Durango) show that the range of these species is in close proximity to Sinaloa. Due to the relative inaccessibility of the Sierra

Table 1. Amphibians and reptiles of Sinaloa with distributional and conservation status. Vegetation Type: 1 = Tropical Deciduous Forest; 2 = Thorn Forest; 3 = Subtropical Mimosaceae Cacti; 4 = Oak Forest; 5 = Pine-Oak Forest; 6 = Marine; 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 2019-2 (www.iucnredlist.org; accessed 26 October 2019); 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); conservation status in Mexico according to SEMARNAT (2010): P = in danger of extinction, A = threatened, Pr = subject to special protection, NL – not listed; Global Distribution: 0 = Endemic to Sinaloa; 1 = Endemic to Mexico; 2 = Shared between the US and Mexico; 3 = widely distributed from Mexico to Central or South America; 4 = widely distributed from the US to Central or South America; 5 = circumglobal distribution; 6 = Pacific and Indian Oceans; IN = Introduced to Sinaloa. Date in which the first record appeared; and Source of the first record.

	Vegetation type	IUCN Status	EVS	SEMARNAT	Global distribution	Date of first record	Source
Class Amphibia							
Order Anura							
Bufonidae							
Anaxyrus cognatus (Say, 1823)	3	LC	L (8)	NL	2	1974	UAZ Herpetology UAZ 38720
Anaxyrus kelloggi (Taylor, 1936)	1, 2, 3, 4	LC	H (14)	NL	1	1936	Taylor 1936
Anaxyrus mexicanus (Brocchi, 1879)	4, 5	NT	M (13)	NL	1	2009	Enderson et al. 2009
Anaxyrus punctatus (Baird & Girard, 1852)	1, 2, 3, 4	LC	L (5)	NL	2	1934	FMNH Amphibians and Reptiles 102426
Incilius alvarius (Girard, 1859)	1, 2, 3	LC	M (11)	NL	2	1953	MVZ:Herp:58724
Incilius marmoreus (Wiegmann, 1833)	1, 2, 4	LC	M (11)	NL	1	1925	CAS HERP 64980
Incilius mazatlanensis (Taylor, 1940)	1, 2, 4	LC	M (12)	NL	1	1940	Taylor 1940
Incilius occidentalis (Camerano, 1879)	4, 5	LC	M (11)	NL	1	1946	MVZ:Herp:44692
Rhinella horribilis (Wiegmann, 1833)	1, 2, 3, 4	NE	NE	NL	4	1905	UAZ Herpetology UAZ 55928
Craugastoridae							
Craugastor augusti (Dugès, 1879)	1, 4	LC	L (8)	NL	2	1955	KU KUH 41556
Craugastor hobartsmithi (Taylor, 1937)	1, 4	EN	H (15)	NL	1	1963	KU KUH 75259
Craugastor occidentalis (Taylor, 1941)	1, 4	DD	M (13)	NL	1	1897	USNM Amphibians & Reptiles 47433
Craugastor pygmaeus (Taylor, 1937)	1, 4	VU	L (9)	NL	1	1963	CAS HERP 175697
Craugastor vocalis (Taylor, 1940)	1, 4	LC	M (13)	NL	1	1955	KU KUH 41530
Eleutherodactylidae							
Eleutherodactylus interorbitalis (Langebartel & Shannon, 1956)	1, 4	DD	H (15)	Pr	1	1955	USNM Amphibians & Reptiles 139727
Eleutherodactylus nitidus (Peters, 1870)	1, 4	LC	M (12)	NL	1	1962	LACM Herps 90544

	Vegetation type	IUCN Status	EVS	SEMARNAT	Global distribution	Date of first record	Source
Eleutherodactylus saxatilis (Webb, 1962)	4	EN	H (17)	NL	1	1961	KU KUH 63326
Eleutherodactylus teretistes (Duellman, 1958)	1, 4	DD	H (16)	Pr	1	1963	KU KUH 75264
Hylidae							
Dryophytes arenicolor (Cope, 1886)	1, 4, 5	LC	L (7)	NL	2	1920	USNM Amphibians & Reptiles 84411
Dryophytes eximius (Baird, 1854)	5	LC	M (10)	NL	1	2019	https://www.inaturalist.org/taxa/65551-Hyla-eximia
Exerodonta smaragdina (Taylor, 1940)	1, 4	LC	M (12)	Pr	1	1957	KU KUH 68719
Sarcohyla bistincta (Cope, 1877)	1, 4	LC	L (9)	Pr	1	1955	KU KUH 44567
Smilisca baudinii (Duméril & Bibron, 1841)	1, 2, 3, 4	LC	L (3)	NL	4	1955	Smith and Van Gelder 1955
Smilisca fodiens (Boulenger, 1882)	1, 2, 3, 4	LC	L (8)	NL	2	1882	Boulenger 1882
Tlalocohyla smithii (Boulenger, 1902)	1, 2, 4	LC	M (11)	NL	1	1953	UMMZ Herps 110915
Trachycephalus vermiculatus (Cope, 1877)	2	NE	L (4)	NL	3	1962	LACM Herps 6316
Tripion spatulatus Günther, 1882	1, 2	LC	M (13)	NL	1	1882	Günther 1882
Leptodactylidae							
Leptodactylus melanonotus (Hallowell, 1861)	1, 2, 3, 4	LC	L (6)	NL	3	1894	CAS HERP 3161
Microhylidae							
Gastrophryne mazatlanensis (Taylor, 1943)	1, 2, 4	NE	L (8)	NL	2	1943	Taylor 1943
Hypopachus ustus (Cope, 1866)	1, 2	LC	L (7)	Pr	3	1918	USNM Amphibians & Reptiles 73267
Hypopachus variolosus (Cope, 1866)	1, 2	LC	L (4)	NL	4	1883	Boulenger 1883
Phyllomedusidae							
Agalychnis dacnicolor (Cope, 1864)	1, 2, 4	LC	M (13)	NL	1	1960	UF Herp 12855
Ranidae							
Rana catesbeiana Shaw, 1802	**NA**	**NA**	**NA**	**NA**	**NA**	**IN**	
Rana forreri Boulenger, 1883	1, 2, 4	LC	L (3)	Pr	3	1883	Boulenger 1883
Rana magnaocularis Frost & Bagnara, 1976	1, 2, 3, 4	LC	M (12)	NL	1	1818	MVZ:Herp:175932
Rana pustulosa Boulenger, 1883	1, 2, 4	LC	L (3)	Pr	1	1953	MVZ:Herp:58962
Rana tarahumarae Boulenger, 1917	4, 5	VU	L (8)	NL	2	1985	UAZ Herpetology UAZ 46087
Scaphiopodidae							
Scaphiopus couchi Baird, 1854	1, 2, 3, 4	LC	L (3)	NL	2	1970	UTEP:Herp:5902
Order Caudata							
Ambystomatidae							
Ambystoma rosaceum Taylor, 1941	4, 5	LC	H (14)	Pr	1	1954	CAS SUA 18388

	Vegetation type	IUCN Status	EVS	SEMARNAT	Global distribution	Date of first record	Source
Class Reptilia							
Order Crocodylia							
Crocodylidae							
Crocodylus acutus Cuvier, 1807	1, 2	VU	H (14)	Pr	4	1912	LACM Herps 138123
Order Squamata							
Suborder Lacertilia							
Anguidae							
Barisia ciliaris (Smith, 1942)	4, 5	NE	H (15)	NL	1	1904	AMNH Herpetology R-585
Elgaria kingii Gray, 1838	1, 4, 5	LC	M (10)	Pr	2	1963	KU KUH 78903
Gerrhonotus liocephalus Wiegmann, 1828	4	LC	L (6)	Pr	2	1961	UMMZ Herps 123044
Dactyloidae							
Anolis nebulosus (Wiegmann, 1834)	1, 2, 3, 4	LC	M (13)	NL	1	1834	Wiegmann 1834
Anolis utowanae Barbour, 1932	1	DD	H (17)	Pr	0	1932	Barbour 1932
Eublepharidae							
Coleonyx fasciatus (Boulenger, 1885)	1, 2	LC	H (17)	NL	1	1963	CAS HERP 115551
Coleonyx variegatus (Baird, 1858)	3	LC	M (11)	Pr	2	1963	LACM Herps 93673
Gekkonidae (Introduced)							
Geyhra mutilata (Wiegmann, 1834)	**NA**	**NA**	**NA**	**NA**	**NA**		
Hemidactylus frenatus Schlegel, 1836	**NA**	**NA**	**NA**	**NA**	**NA**		
Helodermatidae							
Heloderma horridum Wiegmann, 1829	1, 2	LC	M (11)	A	3	1700	MCZ Herp R-7012
Heloderma suspectum Cope, 1869	3	NT	H (15)	A	2	1966	TNHC Herpetology 107291
Iguanidae							
Ctenosaura macrolopha Smith, 1972	1, 2	NE	H (19)	NL	1	1904	USNM Amphibians & Reptiles 33571
Ctenosaura pectinata (Wiegmann, 1834)	1, 2	NE	H (15)	NL	1	1886	Cope 1886
Dipsosaurus dorsalis (Baird & Girard, 1852)	3	LC	M (11)	NL	2	1933	LACM Herps 8646
Iguana iguana (Linnaeus, 1758)	1, 2	LC	M (12)	Pr	3	1894	CAS SUR 2868
Phrynosomatidae							
Callisaurus draconoides Blainville, 1835	1, 2, 3	LC	M (12)	A	2	1894	CAS HERP 3390
Holbrookia elegans Bocourt, 1874	1, 2, 4	LC	M (13)	NL	2	1874	Bocourt 1874
Phrynosoma solare Gray, 1845	1, 2, 3, 4	LC	H (14)	NL	2	1898	USNM Amphibians & Reptiles 47541
Sceloporus albiventris Smith, 1939	1, 2, 4	NE	H (16)	NL	1	1897	USNM Amphibians & Reptiles 47678
Sceloporus bulleri Boulenger, 1894	1, 4	LC	H (15)	NL	1	1946	MVZ:Herp:44695
Sceloporus clarkii Baird & Girard, 1852	1, 2, 3, 4	LC	M (10)	NL	2	1893	Stejneger 1893
Sceloporus jarrovii Cope, 1875	1, 4, 5	LC	M (11)	NL	2	1956	UAZ Herpetology UAZ 02688

	Vegetation type	IUCN Status	EVS	SEMARNAT	Global distribution	Date of first record	Source
Sceloporus magister Hallowell, 1854	1, 2, 3	LC	L (9)	NL	2	1961	CM Herps 38193
Sceloporus nelsoni Cochran, 1923	1, 2	LC	M (13)	NL	1	1923	Cochran 1923
Sceloporus poinsettii Baird & Girard, 1852	4, 5	LC	M (12)	NL	2	1954	LACM Herps 97377
Sceloporus shannonorum Langebartel, 1959	4	NE	H (15)	NL	1	1959	UCM:Herp:12951
Sceloporus spinosus Weigmann, 1828	1, 2, 4, 5	LC	M (12)	NL	1	1959	UCM:Herp:12949
Sceloporus utiformis Cope, 1864	1, 2	LC	H (15)	NL	1	1897	USNM Amphibians & Reptiles 47687
Sceloporus virgatus Smith, 1938	4	LC	H (15)	NL	2	1969	CAS HERP 155905
Urosaurus bicarinatus (Duméril, 1856)	1, 2	LC	M (12)	NL	1	1934	FMNH Amphibians and Reptiles 106516
Urosaurus ornatus (Baird & Girard, 1852)	1, 2	LC	M (10)	NL	2	1899	USNM Amphibians & Reptiles 46628
Phyllodactylidae							
Phyllodactylus homolepidurus Smith, 1935	1, 2	LC	H (15)	Pr	1	1964	LACM Herps 93782
Phyllodactylus lanei Smith, 1935	1, 2	LC	H (15)	NL	1	1936	Taylor 1936
Phyllodactylus tuberculosus Wiegmann, 1835	1, 2	LC	L (8)	NL	3	1897	Van Denburgh 1897
Scincidae							
Plestiodon callicephalus (Bocourt, 1879)	1, 2, 4	LC	M (12)	NL	2	1962	KU KUH 73745
Plestiodon colimensis (Taylor 1935)	1, 2	DD	H (14)	Pr	1	1955	KU KUH 44733
Plestiodon parviauriculatus (Taylor, 1933)	1, 2, 4	DD	H (15)	Pr	1	1967	CAS HERP 155915
Plestiodon parvulus (Taylor, 1933)	2, 4	DD	H (15)	NL	1	1964	KU KUH 91415
Teiidae							
Aspidoscelis communis (Cope, 1978)	1, 2	LC	H (14)	Pr	1	1897	Van Denburgh 1897
Aspidoscelis costatus (Cope, 1878)	1, 2, 3	LC	M (11)	Pr	1	1953	MVZ: Herp:59184
Aspidoscelis stictogrammus (Burger, 1950)	1, 2, 3	LC	H (14)	NL	2	1974	CAS HERP 222149
Aspidoscelis tigris (Baird & Girard, 1852)	1, 2, 3	LC	L (8)	NL	2	1955	KU KUH 44724
Order Squamata							
Suborder Serpentes							
Boidae							
Boa sigma Smith, 1943	1, 2, 3	NE	H (15)	NL	1	1898	USNM Amphibians & Reptiles 46503
Colubridae							
Arizona elegans Kennicott, 1859	1, 2	LC	L (5)	NL	1	1962	CAS HERP 93858
Chilomeniscus stramineus Cope, 1860	1, 2	LC	L (8)	Pr	2	1975	LACM Herps 121310
Conopsis nasus Günther, 1858	4, 5	LC	M (11)	NL	1	1963	CAS SUR 23795

	Vegetation type	IUCN Status	EVS	SEMARNAT	Global distribution	Date of first record	Source
Drymarchon melanurus (Duméril, Bribon & Duméril, 1854)	1, 2, 3, 4	LC	L (6)	NL	4	1897	USNM Amphibians & Reptiles 46430
Drymobius margaritiferus (Schlegel, 1837)	1, 2	LC	L (6)	NL	4	1957	MSUM HE HE. 180
Geagras redimitus Cope, 1875	1, 2	DD	H (14)	Pr	1	1936	Taylor 1936
Gyalopion quadrangulare (Günther, 1893)	1, 2, 3	LC	M (11)	Pr	2	1893	Günther 1893
Lampropeltis greeri Webb, 1961	1, 4	NE	NE	NL	1	2009	Enderson et al. 2009
Lampropeltis nigrita Zweifel & Norris, 1955	1, 2, 3	NE	NE	NL	2	1961	LACM Herps 75333
Lampropeltis polyzona Cope, 1860	1, 2, 3	LC	L (7)	NL	1	1953	MVZ: Herp:59295
Lampropeltis webbi Bryson, Dixon & Lazcano, 2005	4	DD	H (16)	NL	1	2005	Bryson et al. 2005
Leptophis diplotropis (Günther, 1872)	1, 2, 3, 4	LC	H (14)	A	1	1897	Van Denburgh 1897
Masticophis bilineatus Jan, 1863	1, 2, 3	LC	M (11)	NL	2	|894	CAS HERP 3391
Masticophis flagellum Shaw, 1802	1, 2, 3	LC	L (8)	A	2	1904	USNM Amphibians & Reptiles 33570
Masticophis mentovarius (Duméril, Bribon & Duméril, 1854	1, 2, 3, 4	LC	L (6)	A	3	1959	UAZ Herpetology UAZ 16305
Mastigodryas cliftoni (Hardy, 1964)	1, 4	NE	H (14)	NL	1	1962	KU KUH 73490
Mastigodryas melanolomus (Cope 1868)	1, 2	LC	L (6)	NL	3	1963	KU KUH 80746
Oxybelis aeneus (Wagler, 1824)	1, 2	NE	L (5)	NL	4	1925	CAS HERP 64981
Phyllorhynchus browni Stejneger, 1890	1, 2, 3	LC	M (13)	Pr	2	1954	KU KUH 37597
Phyllorhynchus decurtatus (Cope, 1868)	1, 2, 3	LC	M (11)	NL	2	1962	KU KUH 73609
Pituophis catenifer (Blainville, 1835)	1, 2, 3, 4	LC	L (9)	NL	2	1953	MVZ: Herp:59289
Pituophis deppei (Dumeril, 1853)	4	LC	H (14)	A	1	1975	LACM Herps 136856
Pseudoficimia frontalis (Cope, 1864)	1, 2	LC	M (13)	NL	1	1958	LACM Herps 103652
Rhinocheilus lecontei Baird & Girard, 1853	1, 2	LC	L (8)	NL	2	1956	UMMZ Herps 114488
Salvadora bairdii Jan & Sordelli, 1860	1, 2, 4	LC	H (15)	Pr	1	1961	MSUM HE HE. 11367
Salvadora deserticola Schmidt, 1940	1, 2, 3	NE	H (14)	NL	2	1910	Smith 1941
Salvadora hexalepis (Cope, 1867)	1, 2, 3	LC	M (10)	NL	2	1962	KU KUH 73627
Senticolis triaspis (Cope, 1866)	1, 2	LC	L (6)	NL	4	1960	LACM Herps 103798
Sonora aemula (Cope, 1879)	1, 2, 4	NT	H (16)	Pr	1	1956	UAZ Herpetology UAZ 16533
Sonora mutabilis Stickel, 1943	1, 2	LC	H (14)	NL	1	⁇	UTA UTA-R 7227

	Vegetation type	IUCN Status	EVS	SEMARNAT	Global distribution	Date of first record	Source
Sympholis lippiens Cope, 1862	1, 2	NE	H (14)	NL	1	1960	LACM Herps 103696
Tantilla bocourti (Günther, 1895)	1, 4	LC	L (9)	NL	1	1968	CAS HERP 155923
Tantilla calamarina Cope, 1866	2	LC	M (12)	Pr	1	1875	Cope 1875
Tantilla wilcoxi Stejneger, 1902	4, 5	LC	M (10)	NL	2	1968	CAS HERP 155925
Tantilla yaquia Smith, 1942	1, 2	LC	M (10)	NL	2	1925	CAS HERP 64976
Trimorphodon paucimaculatus Taylor, 1936	1, 2, 3, 4	NE	H (15)	NL	1	1936	Taylor 1936
Trimorphodon tau Cope, 1870	1, 2	LC	M (13)	NL	1	1953	FMNH Amphibians and Reptiles 71531
Dipsadidae							
Coniophanes lateritius Cope, 1862	1, 2	DD	M (13)	NL	1	1963	KU KUH 83401
Diadophis punctatus (Linnaeus, 1766)	4	LC	L (4)	NL	2	1964	UTEP:Herp:4026
Geophis dugesii Bocourt, 1883	4	LC	M (13)	NL	1	1972	CM Herps 69071
Hypsiglena chlorophaea Cope, 1860	1, 2, 3	NE	L (8)	NL	2	1956	TCWC Herpetology 12603
Hypsiglena torquata (Günther, 1860)	1, 2	LC	L (8)	Pr	1	1894	CAS HERP 3394
Imantodes gemmistratus (Cope, 1861)	1, 2, 3	LC	L (6)	Pr	3	1956	UMMZ Herps 114466
Leptodeira maculata (Hallowell, 1861)	1, 2	LC	L (7)	Pr	1	1918	USNM Amphibians & Reptiles 62201
Leptodeira punctata (Peters, 1866)	1, 2, 3	LC	H (17)	NL	1	1897	Van Denburgh 1897
Leptodeira splendida Günther, 1895	1, 2	LC	H (14)	NL	1	1897	USNM Amphibians & Reptiles 46459
Rhadinaea hesperia Bailey, 1940	1, 4	LC	M (10)	Pr	1	1897	USNM Amphibians & Reptiles 46456
Tropidodipsas annulifera (Boulenger, 1894)	1, 2	LC	M (13)	Pr	1	1960	LACM Herps 7115
Tropidodipsas philippi (Jan, 1863)	1, 2	LC	H (14)	Pr	1	1962	KU KUH 73640
Elapidae							
Hydrophis platurus (Linnaeus, 1766)	6	LC	NE	NL	6	1951	SDNHM Herps 41205
Micruroides euryxanthus (Kennicott, 1860)	1, 2	LC	H (15)	A	2	1956	UMMZ Herps 114637
Micrurus distans (Kennicott, 1860)	1, 2, 3	LC	H (14)	Pr	1	1962	LACM Herps 7187
Leptotyphlopidae							
Rena dugesii (Bocourt, 1881)	1, 2	NE	NE	NL	1	1894	CAS SUR 1776
Natricidae							
Storeria storerioides (Cope, 1865)	4, 5	LC	M (11)	NL	1	1961	UMMZ Herps 123036
Thamnophis cyrtopsis (Kennicott, 1860)	1, 2, 3, 4	LC	L (7)	A	4	1897	USNM Amphibians & Reptiles 46457
Thamnophis validus (Kennicott, 1860)	1, 2, 3	NE	M (12)	NL	1	1879	Fischer 1879

	Vegetation type	IUCN Status	EVS	SEMARNAT	Global distribution	Date of first record	Source
Typhlopidae							
Indotyphlops braminus (Daudin, 1803)	**NA**	**NA**	**NA**	**NA**	**NA**		
Viperidae							
Agkistrodon bilineatus (Günther, 1863)	1, 2	NT	M (11)	Pr	3	1961	UTEP:Herp:4022
Crotalus atrox Baird & Girard, 1853	3	LC	L (9)	Pr	2	1953	MVZ:Herp:59310
Crotalus basiliscus (Cope, 1864)	1, 2, 3, 4	LC	H (16)	Pr	1	1925	CAS HERP 64974
Crotalus lepidus (Kennicott, 1861)	4	LC	M (12)	Pr	2	1953	MVZ:Herp:59310
Crotalus molossus Baird & Girard, 1853	1, 2, 4	LC	L (8)	Pr	2	1963	KU KUH 78964
Crotalus stejnegeri Dunn, 1919	1	VU	H (17)	A	1	1919	Dunn 1919
Order Testudines							
Chelonidae							
Caretta caretta (Linnaeus, 1758)	6	VU	NE	P	5	1969	Hardy and McDiarmid 1969
Chelonia mydas (Linnaeus, 1758)	6	EN	NE	P	5	1960	UF Herp 39694
Eretmochelys imbricata (Linnaeus, 1766)	6	CR	NE	P	5	1969	Hardy and McDiarmid 1969
Lepidochelys olivacea (Eschscholtz, 1829)	6	VU	NE	P	5	1882	USNM Amphibians & Reptiles 211387
Dermochelyidae							
Dermochelys coriacea (Vandelli, 1761)	6	VU	NE	P	5	1969	Hardy and McDiarmid 1969
Emydidae							
Terrapene nelsoni Stejneger, 1925	1, 2	DD	H (18)	Pr	1	1962	LACM Herps 164113
Trachemys nebulosa (Van Denburgh, 1895)	3	NE	H (18)	NL	1	1965	UMNH:Herp:6040
Trachemys ornata (Gray, 1831)	1, 2	VU	H (19)	Pr	1	1831	Gray 1831
Geoemydidae							
Rhinoclemmys pulcherrima (Gray, 1855)	1, 2, 3	NE	L (8)	NL	3	1868	ANSP HRP
Kinosternidae							
Kinosternon alamosae Berry & Legler, 1980	1, 2, 3	DD	H (14)	Pr	1	1957	LACM Herps 105397
Kinosternon hirtipes (Wagler, 1830)	1, 2	LC	M (10)	Pr	2	1936	Taylor 1936
Kinosternon integrum LeConte, 1854	1, 2, 3	LC	M (11)	Pr	1	1882	USNM Amphibians & Reptiles 12607
Testudinidae							
Gopherus evgoodei Edwards, Karl, Vaughn, Rosen, Meléndez-Torres & Murphy, 2016	1, 2, 3	VU	NE	NL	1	1963	CAS HERP 142243

Madre Occidental in eastern Sinaloa, and the lack of security in this region, these species have not yet been documented, but as conditions improve it is likely that they will be recorded in Sinaloa. The results of the species accumulation curves suggest that after a

Table 2. List of amphibian and reptile species that potentially occur in Sinaloa.

Taxon	Explanation
Class Amphibia	
Order Anura	
Bufonidae	
Anaxyrus compactilis (Wiegmann, 1833)	Likely to occur in eastern Sinaloa
Incilius mccoyi Santos-Barrera & Flores-Villela, 2011	Likely to occur in northeastern Sinaloa
Craugastoridae	
Craugastor tarahumaraensis (Taylor, 1940)	Likely to occur in northeastern Sinaloa
Eleutherodactylidae	
Eleutherodactylus pallidus (Duellman, 1958)	Likely to occur in southeastern Sinaloa
Hylidae	
Dryophytes wrightorum (Taylor, 1939)	Likely to occur in northeastern Sinaloa
Ranidae	
Rana chiricahuensis Platz & Mecham, 1979	Likely to occur in eastern Sinaloa
Order Caudata	
Ambystomatidae	
Ambystoma silvense Webb, 2004	Likely to occur in eastern Sinaloa
Class Reptilia	
Order Squamata	
Suborder Lacertilia	
Eublepharidae	
Coleonyx elegans Gray, 1845	Likely to occur in southern Sinaloa
Phrynosomatidae	
Sceloporus grammicus Wiegmann, 1828	Likely to occur in eastern Sinaloa
Sceloporus lemosespinali Lara-Góngora, 2004	Likely to occur in northeastern Sinaloa
Sceloporus scalaris Weigmann, 1828	Likely to occur in eastern Sinaloa
Order Squamata	
Suborder Serpentes	
Dipsadidae	
Rhadinaea laureata (Günther, 1868)	Likely to occur in eastern Sinaloa
Natricidae	
Thamnophis eques (Reuss, 1834)	Likely to occur in eastern-southeastern Sinaloa
Thamnophis errans Smith, 1942	Likely to occur in eastern Sinaloa
Thamnophis melanogaster (Peters, 1864)	Likely to occur in eastern Sinaloa
Thamnophis nigronuchalis Thompson, 1957	Likely to occur in eastern Sinaloa
Thamnophis pulchrilatus (Cope, 1885)	Likely to occur in eastern Sinaloa
Thamnophis unilabialis Tanner, 1985	Likely to occur in northeastern Sinaloa
Viperidae	
Crotalus pricei Van Denburgh, 1895	Likely to occur in eastern and northeastern Sinaloa

steep increase in the number of recorded species of amphibians and reptiles in Sinaloa during the 20th century, the accumulation of newly documented species is leveling off, at least for the entire herpetofauna and for reptiles (Fig. 6). This indicates that the current checklist may be relatively complete, although the continued accumulation of amphibians suggests that there are still likely some species to be discovered in Sinaloa. Thus, we suspect that there may be some additions to the herpetofauna, including those suspected above, that will result from further survey and taxonomic work in Sinaloa in the future.

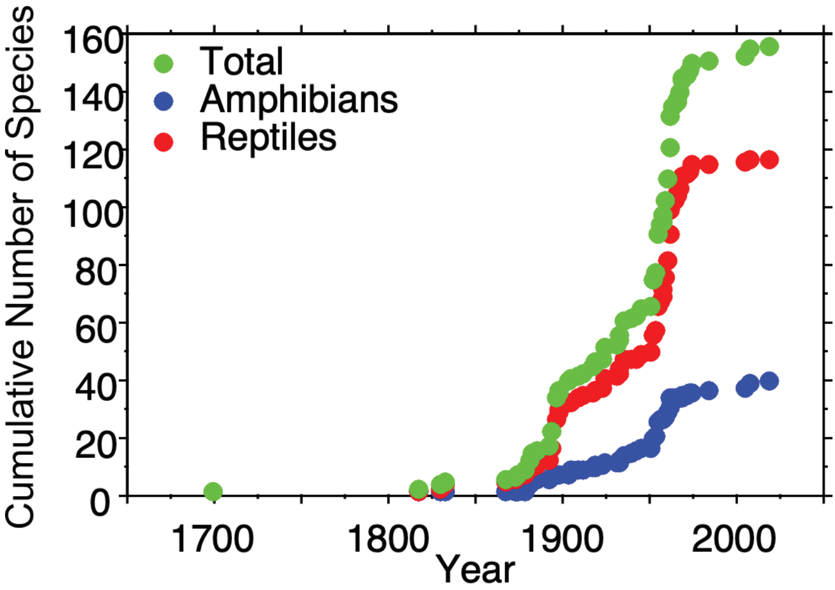

Figure 6. Species accumulation curves for the total herpetofauna, amphibians, and reptiles in Sinaloa, Mexico.

General distribution

Twenty-one of the 39 species of amphibians in Sinaloa are endemic to Mexico, two of which are restricted to small areas in the Sierra Madre Occidental of Sinaloa and adjacent Durango, or Sinaloa, Nayarit, and Jalisco. Twelve are primarily distributed along the Pacific Coast and western slopes of the Sierra Madre Occidental. Two are characteristic of the Sierra Madre Occidental, and five have a widespread or spotty distribution in the Sierra Madre Occidental, central Mexico, and Sierra Madre del Sur. Of the 18 amphibian species in Sinaloa not endemic to Mexico, one is introduced, nine are found in the United States and Mexico, five are distributed from Mexico to Central or South America, and three have a wide distribution from the United States to Central or South America (Table 1). The American Crocodile (*Crocodylus acutus*) is widely distributed from southern Florida in the United States, and along the Pacific Coast of Mexico from Sonora to northern South America, including the Caribbean and the Yucatan Peninsula. Twenty of the 42 species of lizards that occur in the state are endemic to Mexico, one is endemic to Sinaloa, three are restricted to localities in the northern part of the Sierra Madre Occidental, one has a spotty distribution in Sinaloa and Colima, and one has a spotty distribution in the Pacific Coast from Sinaloa to Michoacán. Twelve species are found on the western slopes of the Sierra Madre Occidental and the Pacific Coast, one occurs in both the Sierra Madre Occidental and the Sierra Madre Oriental, and one is widely distributed in northern and central Mexico. The remaining 22 species of lizards that inhabit Sinaloa are not endemic to Mexico. Seventeen of the non-endemic species of lizards are found in the United States and Mexico, three are distributed from Mexico to Central America, and two are introduced to Sinaloa (Table 1). Thirty-four of the 64 species of snakes that inhabit Sinaloa are endemic to Mexico. Of the 30 snake species not endemic to Mexico, 19 are found in the United States and Mexico, four range from Mexico to Central or even South America, five are found from central or southern United States to Central or South America, one is a sea snake distributed across the Pacific and Indo-Pacific Oceans, and one is introduced to Sinaloa (Table 1). Six of the13 species of turtles found in Sinaloa are endemic to Mexico, one is found in the United States and Mexico, one is distributed from Mexico to Central America, and five have a circumtropical or circumglobal distribution (Table 1). One of the six endemic species of turtles that inhabit Sinaloa is shared with Baja California Sur (*Trachemys nebulosa*). This species was probably introduced in the Cape Region of Baja California by Sinaloan miners (T. Van Devender, pers. comm.).

Habitat types

The vegetation type that hosts the highest number of amphibian and reptile species is the Tropical Deciduous Forest, which includes semi-deciduous forest, with 121 species, which represents 77.6% of the total number of species found in Sinaloa. The second highest number of amphibian and reptile species is hosted by "Thorn Forest" with 104 species, which represents 66.7% of the total species of Sinaloa. According to INEGI (2017), these two types of vegetation together occupy approximately 36% of the state. These are the two dominant vegetation types in the state, and they are also the vegetation types that originally appeared in what are now the agricultural areas of Sinaloa, which now occupy approximately 38.5% of the state surface territory (INEGI 2017). In addition, they are the types of vegetation, which due in part to their location, have been more studied from the herpetofaunistic point of view. On the other hand, the Oak Forest of Sinaloa, hosts 70 species (44.9%) of amphibians and reptiles, and the Pine-oak Forest, limited to the highest parts of the Sierra Madre Occidental of Sinaloa, hosts only 14 species (9.0%) of amphibians and reptiles of Sinaloa. Together, these two vegetation types occupy approximately 16.5% of the state surface territory (INEGI 2017). The Subtropical Mimosaceae Cacti thorn scrub vegetation type of Sinaloa hosts 49 species (31.6%) of amphibians and reptiles. This vegetation type, limited to the northwestern tip of the state, occupies < 3.2% of the state's territory; however, it houses a unique assortment of amphibians and reptiles, dominated by species typical of thornscrub (Bezy et al. 2017).

Conservation status

For amphibian and reptile species together, 12.7% are IUCN listed (i.e., Vulnerable, Near Threatened, or Endangered), 9.7% are placed in a protected category (excluding NL and Pr, this last category is equivalent to the LC category of IUCN) by SEMARNAT, and 34.0% are categorized as high risk by the EVS (Table 3). For amphibians,

Table 3. Summary of native species present in Sinaloa 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 1 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). Mean EVS is the mean Environmental Vulnerability Score, scores ≥ 14 are considered high vulnerability (Wilson et al. 2013a, b) and conservation status in Mexico according to SEMARNAT (2010) in the order NL, Pr, A, P (see Table 1 for abbreviations).

Scientific name	Genera	Species	IUCN	$\bar{x}$ EVS	SEMARNAT
Class Amphibia			**DD, LC, VU, NT, EN, CE**		**NL, Pr, A, P**
Order Anura	**18**	**37**	**3, 26, 2, 1, 2, 0**	**9.7**	**30, 7, 0, 0**
Bufonidae	3	9	0, 7, 0, 1, 0, 0	10.6	9, 0, 0, 0
Craugastoridae	1	4	1, 2, 1, 0, 1, 0	12.3	5, 0, 0, 0
Eleutherodactylidae	1	4	2, 1, 0, 0, 1, 0	15	2, 2, 0, 0
Hylidae	7	9	0, 8, 0, 0, 0, 0	8.6	7, 2, 0, 0
Leptodactylidae	1	1	0, 1, 0, 0, 0, 0	6	1, 0, 0, 0
Microhylidae	2	3	0, 2, 0, 0, 0, 0	6.3	2, 1, 0, 0
Phyllomedusidae	1	1	0, 1, 0, 0, 0, 0	13	1, 0, 0, 0
Ranidae	1	4	0, 3, 1, 0, 0, 0	6.5	2, 2, 0, 0
Scaphiopodidae	1	1	0, 1, 0, 0, 0, 0	3	1, 0, 0, 0
Order Caudata	**1**	**1**	**0, 1, 0, 0, 0, 0**	**14**	**0, 1, 0, 0**
Ambystomatidae	1	1	0, 1, 0, 0, 0, 0	14	0, 1, 0, 0
Subtotal	**19**	**38**	**3, 27, 2, 1, 2, 0**	**9.8**	**30, 8, 0, 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	**56**	**103**	**7, 76, 1, 3, 0, 0**	**11.7**	**64, 29, 10, 0**
Suborder Lacertilia	**17**	**40**	**4, 30, 0, 1, 0, 0**	**12.9**	**27, 10, 3, 0**
Anguidae	3	3	0, 2, 0, 0, 0, 0	10.3	1, 2, 0, 0
Dactyloidae	1	2	1, 1, 0, 0, 0, 0	15	1, 1, 0, 0
Eublepharidae	1	2	0, 2, 0, 0, 0, 0	14	1, 1, 0, 0
Helodermatidae	1	2	0, 1, 0, 1, 0, 0	13	0, 0, 2, 0
Iguanidae	3	4	0, 1, 0, 0, 0, 0	14.3	3, 1, 0, 0
Phrynosomatidae	5	16	0, 14, 0, 0, 0, 0	12.8	15, 0, 1, 0
Phyllodactylidae	1	3	0, 3, 0, 0, 0, 0	12.7	2, 1, 0, 0
Scincidae	1	4	3, 1, 0, 0, 0, 0	14	2, 2, 0, 0
Teiidae	1	4	0, 4, 0, 0, 0, 0	11.8	2, 2, 0, 0
Suborder Serpentes	**39**	**63**	**3, 46, 1, 2, 0, 0**	**10.9**	**37, 19, 7, 0**
Boidae	1	1	0, 0, 0, 0, 0, 0	15	1, 0, 0, 0
Colubridae	22	37	2, 27, 0, 1, 0, 0	10.6	26, 7, 4, 0
Dipsadidae	8	12	1, 10, 0, 0, 0, 0	10.6	6, 6, 0, 0
Elapidae	3	3	0, 3, 0, 0, 0, 0	14.5	1, 1, 1, 0
Leptotyphlopidae	1	1	0, 0, 0, 0, 0, 0	–	1, 0, 0, 0
Natricidae	2	3	0, 2, 0, 0, 0, 0	10	2, 0, 1, 0
Viperidae	2	6	0, 4, 1, 1, 0, 0	12.2	0, 5, 1, 0
Order Testudines	**10**	**13**	**2, 2, 5, 0, 1, 1**	**14**	**3, 5, 0, 5**
Cheloniidae	4	4	0, 0, 2, 0, 1, 1	–	0, 0, 0, 4
Dermochelyidae	1	1	0, 0, 1, 0, 0, 0	–	0, 0, 0, 1
Emydidae	2	3	1, 0, 1, 0, 0, 0	18.3	1, 2, 0, 0
Geoemydidae	1	1	0, 0, 0, 0, 0, 0	8	1, 0, 0, 0
Kinosternidae	1	3	1, 2, 0, 0, 0, 0	11.7	0, 3, 0, 0
Testudinidae	1	1	0, 0, 1, 0, 0, 0	–	1, 0, 0, 0
Subtotal	**67**	**117**	**9, 78, 7, 3, 1, 1**	**11.9**	**67, 35, 10, 5**
Total	**86**	**155**	**12, 105, 9, 4, 3, 1**	**11.4**	**97, 43, 10, 5**

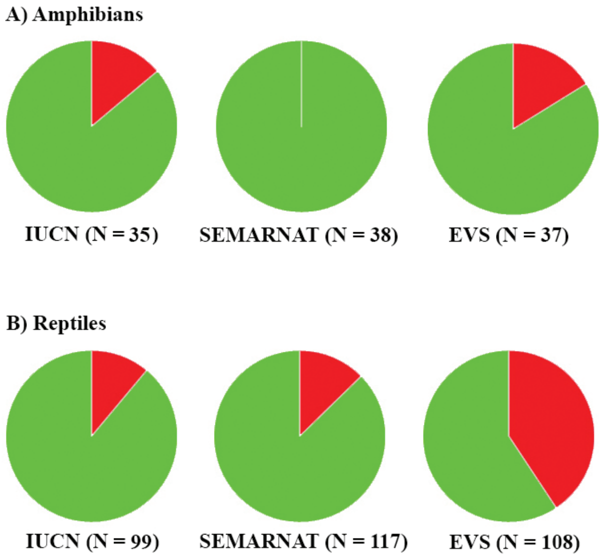

Figure 7. Proportion of **A** amphibians and **B** reptiles listed in protected categories on the IUCN Red List, SEMARNAT, and high EVS for Sinaloa. Green is proportion in Data Deficient and Least Concern (IUCN); Not Listed and Subject to Special Protection (we regarded the category of Subject to Special Protection in SEMARNAT equivalent to Least Concern in IUCN) (SEMARNAT); or low or medium EVS. Red is percentage in protected categories or high EVS. N is the number of species assessed.

14.3% are IUCN listed, none are protected by SEMARNAT, and 16.2% are at high risk according to the EVS (Table 3; Fig. 7). For reptiles, 17.2% are listed by the IUCN, 12.8% are protected by SEMARNAT, and 40.2% are at high risk according to the EVS (Table 3; Fig. 7). This summary suggests that the herpetofauna of Sinaloa has relatively few species of conservation concern at a global and national scale (IUCN and SEMARNAT lists), but there might be greater conservation concerns using the EVS which is based on information specific to Mexico and Central America and so might be more likely to reflect the conservation status and needs of the Sinaloa herpetofauna. Although the SEMARNAT list is also based on information specific to Mexico, it has not been updated since 2010, and so does not take into account the numerous recent taxonomic changes and the description of new species or more recent changes in conservation status or threats. There are several taxa that, based on their IUCN listing, SEMARNAT category, or their EVS, are of conservation concern. Families with species of particular conservation concern include Craugastoridae, Eleutherodactylidae, Ambystomatidae, Crocodylidae, Dactyloidae, Eublepharidae, Helodermatidae, Iguanidae, Phrynosomatidae, Phyllodactylidae, Colubridae, Natricidae, Viperidae, Cheloniidae, and Dermochelyidae (Table 3). The status of a species in Sinaloa may differ (i.e., be worse or better) from the IUCN, SEMARNAT, and EVS assessments. Thus, assessments at the state level are needed to fully understand the conservation or management needs for the Sinaloan herpetofauna.

The conservation status of species found in different vegetation types in Sinaloa appear to differ (Table 1). For IUCN categories, 6.7% of the amphibian species found in the Tropical Deciduous Forest are listed in a protected category; none in the Thorn Forest of the Coastal Plains or the Subtropical Mimosaceae Cacti, 16.1% in the Oak Forest, and 33.3% in the Pine-Oak Forest. For SEMARNAT categories, no species of amphibian in Sinaloa is listed for any vegetation type (see above). For EVS, 13.3% of the amphibians in the Tropical Deciduous Forest of Sinaloa were in the high category, 5.0% in the Thorn Forest, 10.0% in the Subtropical Mimosaceae Cacti, 19.4% in the Oak Forest, and 16.7% in the Pine-oak Forest. For the IUCN listings, all five vegetation types of Sinaloa have relatively few species of reptiles in the protected categories (Tropical Deciduous Forest, 6.6%; Thorn Forest, 6.0%; Subtropical Mimosaceae Cacti, 5.1%; Oak Forest, 2.6%, and Pine-oak Forest, 0%). However, 66.7% of the reptiles in the Marine region are listed in IUCN protected categories. According to SEMARNAT, 8.8% of reptiles that inhabit the Tropical Deciduous Forest of Sinaloa, 8.3% from the Thorn Forest, 15.4% from Subtropical Mimosaceae Cacti, 10.3% from the Oak Forest, and none from the Pine-oak Forest are in protected categories. Five (83.3%) of the marine reptiles of Sinaloa are in protected SEMARNAT categories. For the Tropical Deciduous Forest of Sinaloa 38.5% of the reptile species were in the high EVS category, 38.1% in the Thorn Forest, 33.3% in the Subtropical Mimosaceae Cacti, 41.0% in the Oak Forest, and 12.5% in the Pine-oak Forest. None of the marine reptile species have been evaluated by the EVS. The marine reptiles of Sinaloa are by far the most threatened of the Sinaloa herpetofauna.

Comparison with neighboring states

Overall, Sinaloa shares the most herpetofaunal species with Sonora, with 72.4% overlap in species (Table 4). Sinaloa shares the most amphibian species with Nayarit (78.9%). Some families, including Hylidae, Leptodactylidae, Microhylidae, Scaphiopodidae, and Ambystomatidae, show complete overlap between Sinaloa and Nayarit. The higher similarity in amphibian composition between Nayarit and Sinaloa than between Sinaloa and Sonora is due to eleven species that are shared between Sinaloa and Nayarit but not Sonora. All of these species reach their northern most distribution either in Sinaloa or Durango. The five that are shared between Sinaloa and Sonora but not with Nayarit reach their southern or southwestern most distribution in Sinaloa, and one is a species likely to occur in Nayarit. The similarity between the amphibian composition of Sinaloa and Chihuahua and Durango is lower than for Sonora and Nayarit (55.3% Durango, 52.6% Chihuahua). The amphibian species of Chihuahua and Durango have a number of species from the Chihuahuan Desert and the Sierra Madre Occidental, that do not occur in Sinaloa (Lemos-Espinal et al. 2017, 2019a). On the other hand, the Peninsula of Baja California has the lowest similarity with Sinaloa (18.1%), sharing only 28 species (Table 4), of which six are marine species with a wide global distribution. Eight of the other 22 species are only found in the northern

Table 4. Summary of the numbers of species shared between Sinaloa and neighboring Mexican states (not including introduced species). The percent of Sinaloa species shared by a neighboring state are given in parentheses. Total refers to the total number of species found in Sinaloa and four neighboring states (i.e., regional species pool) and the number in parentheses in this column is the percent of the regional species pool found in Sinaloa. – indicates either Sinaloa or the neighboring state has no species in the taxonomic group, or none of that specific taxon is shared between the states, thus no value for shared species is provided. Peninsula refers to herpetofauna of the states of Baja California and Baja California Sur pooled together.

Taxon	Sinaloa	Sonora	Nayarit	Chihuahua	Durango	Peninsula	Total
Class Amphibia	**38**	**25 (65.8)**	**30 (78.9)**	**20 (52.6)**	**21 (55.3)**	**3 (7.9)**	**77 (49.4)**
Order Anura	**37**	**24 (64.9)**	**29 (78.4)**	**19 (51.4)**	**20 (54.1)**	**3 (8.1)**	**67 (55.2)**
Bufonidae	9	8 (88.9)	5 (55.6)	6 (66.7)	7 (77.8)	2 (22.2)	17 (52.9)
Craugastoridae	5	2 (40)	4 (80)	1 (20)	3 (60)	–	6 (83.3)
Eleutherodactylidae	4	1 (25)	2 (50)	1 (25)	2 (50)	–	6 (66.7)
Hylidae	9	4 (44.4)	9 (100)	3 (33.3)	4 (44.4)	–	14 (64.3)
Leptodactylidae	1	1 (100)	1 (100)	–	–	–	1 (100)
Microhylidae	3	2 (66.7)	3 (100)	2 (66.7)	–	–	4 (75)
Phyllomedusidae	1	1 (100)	1 (100)	1 (100)	1 (100)	–	1 (100)
Ranidae	4	4 (100)	3 (75)	4 (100)	2 (50)	–	14 (28.6)
Scaphiopodidae	1	1 (100)	1 (100)	1 (100)	1 (100)	1 (100)	4 (25)
Order Caudata	**1**	**1 (100)**	**1 (100)**	**1 (100)**	**1 (100)**	–	**10 (10)**
Ambystomatidae	1	1 (100)	1 (100)	1 (100)	1 (100)	–	4 (25)
Plethodontidae	–	–	–	–	–	–	6 (0)
Class Reptilia	**117**	**87 (74.4)**	**76 (65)**	**64 (54.7)**	**57 (48.7)**	**25 (21.4)**	**358 (32.7)**
Order Crocodylia	**1**	**1 (100)**	**1 (100)**	–	–	–	**1 (100)**
Crocodylidae	1	1 (100)	1 (100)	–	–	–	1 (100)
Order Squamata	**103**	**75 (72.8)**	**66 (64.1)**	**58 (57.3)**	**55 (53.4)**	**19 (18.4)**	**332 (31)**
Suborder Amphisbaenia	**–**	–	–	–	–	–	**1 (0)**
Bipedidae	–	–	–	–	–	–	1 (0)
Suborder Lacertilia	**40**	**27 (67.5)**	**20 (50)**	**18 (45)**	**21 (52.5)**	**7 (17.5)**	**177 (22.6)**
Anguidae	3	1 (33.3)	2 (66.7)	2 (66.7)	3 (100)	–	11 (27.3)
Anniellidae						–	2 (0)
Corytophanidae	–	–	–	–	–	–	1 (0)
Crotaphytidae	–	–	–	–	–	–	8 (0)
Dactyloidae	2	1 (50)	1 (50)	1 (50)	1 (50)	–	2 (100)
Eublepharidae	2	2 (100)	–	–	1 (50)	1 (50)	6 (33.3)
Helodermatidae	2	2 (100)	1 (50)	1 (50)	1 (50)	–	2 (100)
Iguanidae	4	2 (50)	2 (50)	1 (25)	1 (25)	2 (50)	12 (33.3)
Phrynosomatidae	16	12 (75)	8 (50)	9 (56.3)	11 (68.8)	3 (18.8)	72 (22.2)
Phyllodactylidae	3	2 (66.7)	2 (66.7)	1 (33.3)	1 (33.3)	–	9 (33.3)
Scincidae	4	2 (50)	2 (50)	2 (50)	1 (25)	–	16 (25)
Teiidae	4	3 (75)	2 (50)	1 (25)	1 (25)	1 (25)	30 (13.3)
Xantusidae	–	–	–	–	–	–	6 (0)
Suborder Serpentes	**63**	**48 (76.2)**	**46 (73.0)**	**41 (65.1)**	**34 (54.0)**	**12 (19.0)**	**154 (40.9)**
Boidae	1	1 (100)	1 (100)	1 (100)	1 (100)	–	3 (33.3)
Colubridae	37	28 (75.7)	23 (62.2)	23 (62.2)	21 (56.8)	7 (18.9)	74 (50)
Dipsadidae	12	7 (58.3)	11 (91.7)	6 (50)	4 (33.3)	2 (16.7)	24 (50)

Taxon	Sinaloa	Sonora	Nayarit	Chihuahua	Durango	Peninsula	Total
Elapidae	3	3 (100)	3 (100)	2 (66.7)	–	1 (33.3)	5 (60)
Leptotyphlopidae	1	1 (100)	1 (100)	1 (100)	–	–	4 (25)
Loxocemidae	–	–	–	–	–	–	1 (0)
Natricidae	3	3 (100)	3 (100)	3 (100)	3 (100)	1 (33.3)	16 (18.8)
Viperidae	6	5 (83.3)	4 (66.7)	5 (83.3)	5 (83.3)	1 (16.7)	27 (22.2)
Order Testudines	**13**	**11 (84.6)**	**9 (69.2)**	**5 (38.5)**	**2 (15.4)**	**6 (46.2)**	**25 (52)**
Cheloniidae	4	4 (100)	3 (75)	–	–	4 (100)	4 (100)
Dermochelyidae	1	1 (100)	1 (100)	–	–	1(100)	1(100)
Emydidae	3	2 (66.7)	2 (66.7)	1 (33.3)	–	1 (33.3)	8 (37.5)
Geoemydidae	1	1 (100)	1 (100)	1 (100)	–	–	1 (100)
Kinosternidae	3	2 (66.7)	2 (66.7)	2 (66.7)	2 (66.7)	–	8 (37.5)
Testudinidae	1	1 (100)	–	1 (100)	–	–	3 (66.7)
Total	**155**	**112 (72.3)**	**106 (68.4)**	**84 (54.2)**	**78 (50.3)**	**28 (18.1)**	**435 (35.6)**

part of the Peninsula, in the state of Baja California, far away from Sinaloa, another 10 species have a wide distribution that includes practically the entire Peninsula and the northern Mexican Pacific, four species are limited to the Baja California Peninsula and the northern part of the Mexican Pacific. Although eight to thirteen million years ago most of the Baja California Peninsula was submerged beneath the Pacific Coast and located next to the northwest coast of mainland Mexico (Grismer 2002), since its separation approximately six million years ago the fauna and flora of this peninsula has evolved under conditions of isolation, giving rise to a unique and different biota than that of Sinaloa. These numbers are an indication that Sonora, Sinaloa, and Nayarit are more similar due to the dominance of species distributed along the Pacific Coast, and Chihuahua and Durango are more similar in the composition of amphibians due to the dominance of species from the Chihuahuan Desert and Sierra Madre Occidental. The great similarity in the herpetofauna composition between Sinaloa and Sonora was also found by Enderson et al. (2009). Similarly, reptile composition is more similar between Sinaloa and its neighbors Sonora and Nayarit, than between neighbors Chihuahua and Durango. As with amphibians, Chihuahua and Durango have more reptile species from the Chihuahuan Desert and the Sierra Madre Occidental, and few species characteristic of the Pacific Coast. In addition, Sonora, Sinaloa, and Nayarit share a number of reptile species characteristic of the Pacific Coast. A greater similarity between Sonora, Sinaloa, and Nayarit is also expected by the presence of marine species in these three states, and an absence of those species in Chihuahua and Durango.

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References

AmphibiaWeb (2019) AmphibiaWeb. University of California, Berkeley, CA, USA. https://amphibiaweb.org [Accessed 20 October 2019]

Barbour T (1932) On a new *Anolis* from Western Mexico. Copeia 1932(1): 11–12. https://doi.org/10.2307/1437022

Beltrán JA (2017) Ven crisis ambiental en Sinaloa. Periódico Noroeste. https://www.noroeste.com.mx/publicaciones/view/ven-crisis-ambiental-en-sinaloa-1072500

Bezy RL, Rosen PC, Van Devender TR, Enderson EF (2017) Southern distributional limits of the Sonoran Desert herpetofauna along the mainland coast of northwestern Mexico. Mesoamerican Herpetology 4: 138–167.

Boucourt MF (1874) Mission scientifique au Mexique et dans l'Amérique Centrale. Reptiles, 164. [pl. xvii. Bis. fig. 8]

Boulenger GA (1882) Description of a new genus and species of frogs of the family Hylidae. Annals and Magazine of Natural History 5(10): 326–328. https://doi.org/10.1080/00222938209459716

Boulenger GA (1883) Descriptions of new species of lizards and frogs collected by Herr A. Forrer in Mexico. Annals and Magazine of Natural History 5(11): 342–344. https://doi.org/10.1080/00222938309459162

Brand DD (1936) Notes to accompany a vegetation map of northwest Mexico. University of New Mexico Bulletin 280, 4(4): 1–27.

Bryson RW, Dixon JR, Lazcano D (2005) New species of *Lampropeltis* (Serpentes: Colubridae) from the Sierra Madre Occidental, México. Journal of Herpetology 39: 207–214. https://doi.org/10.1670/85-04A

Cervantes-Zamora Y, Cornejo-Olgín SL, Lucero-Márquez R, Espinoza-Rodríguez JM, Miranda-Viquez E, Pineda-Velázquez A (1990) 'Provincias Fisiográficas de México'. Extraído de Clasificación de Regiones Naturales de México II, IV.10.2. Atlas Nacional de México. Vol. II. Escala 1:4000000. Instituto de Geografía, UNAM. México.

Cochran DM (1923) A New Lizard of the Genus *Sceloporus*. Journal of the Washington Academy of Sciences 13(9): 185–186. https://doi.org/10.5962/bhl.part.5294

Cope ED (1875) On the Batrachia and Reptilia of Costa Rica with notes on the herpetology and ichthyology of Nicaragua and Peru. Journal of the Academy of Natural Sciences of Philadelphia N.S. (2)8: 93–183. https://doi.org/10.5962/bhl.title.5028

Cope ED (1886) On the species of Iguaninae. Proceedings of the American Philosophical Society 23(122): 261–271.

Dunn ER (1919) Two new crotaline snakes from western Mexico. Proceedings of the Biological Society of Washington 32: 213–216.

Enderson EF, Van Devender TR, Bezy RL (2014) Amphibians and reptiles of Yécora, Sonora and the Madrean Tropical Zone of the Sierra Madre Occidental in northwestern Mexico. Check List 10: 913–926. https://doi.org/10.15560/10.4.913

Enderson EF, Quijada-Mascareña A, Turner DS, Rosen PC, Bezy RL (2009) The herpetofauna of Sonora, Mexico, with comparison to adjoining states, Check List 5: 632–672. https://doi.org/10.15560/5.3.632

Fischer JG (1879) Neue order wenig bekannte Reptilien. Verhandlungen Naturwissenschaften Verein Hamburg-Altona (new series 3) 1878: 78–103.

Frost DR (2019) Amphibian Species of the World: an Online Reference. Version 6.0. American Museum of Natural History, New York. http://research.amnh.org/herpetology/amphibia/index.html [Accessed on 20 October 2019]

García E (1998) Modificaciones al sistema de clasificación climática de Köppen. Instituto de Geografía – UNAM, 90 pp.

García E, Comisión Nacional para el Conocimiento y Uso de la Biodiversidad [CONABIO] (1998) "Climas (Clasificación de Köppen, modificado por García)". Escala 1:1 000 000. México.

García-Martínez B (2008) La Vertiente del Norte: El Noroeste. Las Regiones De México: Breviario Geográfico e Histórico, 1st ed., Colegio De México, México, 215–240. https://doi.org/10.2307/j.ctvhn0d4x.8

Gray JE (1831) A synopsis of the species of Class Reptilia. In: Griffith E, Pidgeon E (Eds) The animal kingdom arranged in conformity with its organisation by the Baron Cuvier with additional descriptions of all the species hither named, and of many before noticed [V Whittaker, Treacher and Co., London, 481 + 110 pp. [1830]

Günther ACLG (1882) Notice of a second species of *Triprion*. Annals and Magazine of Natural History 5(10): 279. https://doi.org/10.1080/00222938209459709

Hardy LM, McDiarmid RW (1969) The amphibians and reptiles of Sinaloa, Mexico. University of Kansas Publications, Museum of Natural History 18(3): 39–252. https://doi.org/10.5962/bhl.part.19990

INEGI (2009) 'Modelo digital de terreno, escala: 1:250000. Instituto Nacional de Estadística y Geografía. Aguascalientes, Aguascalientes.

INEGI (2013) 'Conjunto de datos vectoriales de uso de suelo y vegetación escala 1:250 000, serie V (capa unión)', escala: 1:250000. edición: 2a. Instituto Nacional de Estadística y Geografía. Aguascalientes, Aguascalientes.

INEGI (2017) Anuario estadístico y geográfico de Sinaloa 2017 / Instituto Nacional de Estadística y Geografía. México, 475 pp.

INEGI (2018a) 'Áreas Geoestadísticas Estatales', escala: 1:250000. edición: 1. Instituto Nacional de Estadística y Geografía. Aguascalientes, México.

INEGI (2018b) 'Áreas Geoestadísticas Municipales', escala: 1:250000. edición: 1. Instituto Nacional de Estadística y Geografía. Aguascalientes, México.

IUCN (2019) IUCN Red List of Threatened Species, Version 2019.2. [Downloaded on 24 October 2019]

Johnson JD, Mata-Silva V, Wilson LD (2015) A conservation reassessment of the Central American herpetofauna based on the EVS measure. Amphibian & Reptile Conservation 9: 1–94.

Lemos-Espinal JA, Smith GR, Gadsden-Esparza H, Valdez-Lares R, Woolrich-Piña GA (2018a) Amphibians and reptiles of the state of Durango, Mexico, with comparisons with adjoining states. ZooKeys 748: 65–87. https://doi.org/10.3897/zookeys.748.22768

Lemos-Espinal JA, Smith GR, Rorabaugh J (2019a) A conservation checklist of the amphibians and reptiles of Sonora, Mexico, with updated species lists. Zookeys 829: 131–160. https://doi.org/10.3897/zookeys.829.32146

Lemos Espinal JA, Smith GR, Valdez-Lares R (2019b) Amphibians and Reptiles of Durango, México. ECO-Herpetological Publishing and Distribution, Rodeo New Mexico, 414 pp.

Lemos-Espinal JA, Smith GR, Woolrich-Piña GA, Cruz A (2017) Amphibians and reptiles of the state of Chihuahua, Mexico, with comparisons with adjoining states. ZooKeys 658: 105–130. https://doi.org/10.3897/zookeys.658.10665

Lemos-Espinal JA, Smith HM (2007) Anfibios y Reptiles del Estado de Chihuahua, México/ Amphibians and Reptiles of the State of Chihuahua, Mexico. CONABIO, México, 628 pp.

Manzano-Sarabia M, Millan-Aguilar O, Flores-Cardenas F, Rodríguez-Arredondo L, Grano-Maldonado MI, Nieves-Soto M (2018) Current status of mangrove wetlands in Sinaloa: A biological corridor along the eastern margin of the Gulf of California. In: Makowski C, Finkl CW (Eds) Threats to Mangrove Forests: Hazards, Vulnerability, and Management. Coastal Research Library, Mexico, 77–87. https://doi.org/10.1007/978-3-319-73016-5_4

Martin PS, Yetman DA, Fishbein M, Jenkins P, Van Devender TR, Wilson RK (1998) Gentry's Rio Mayo Plants: The Tropical Deciduous Forest and Environs of Northwest Mexico. University of Arizona Press, Tucson, 558 pp.

Mejia-Radillo RY, Zavala-Norzagaray AA, Chavez-Medina A, Aguirre AA, Escobedo-Bonilla CM (2019) Presence of chelonid herpesvirus 5 (ChHV5) in sea turtles in northern Sinaloa, Mexico. Disease of Aquatic Organisms 132: 99–108. https://doi.org/10.3354/dao03313

Muñoz Sevilla NP, Villanueva-Fonseca BP, Gougora-Gomez AM, García-Ulloa M, Domínguez-Orozco AL, Ortega-Izaguirre R, Campos Villegas LE (2017) Heavy metal concentrations in diploid and triploid oysters (*Crassastrea gigas*) from three farms on the north-central coast of Sinaloa, Mexico. Environmental Monitoring and Assessment 189(11): 536. https://doi.org/10.1007/s10661-017-6223-9

Quinones PH, Unland H, Ojeda W, Sifuentes E (1999) Transfer of irrigation scheduling technology in Mexico. Agricultural Water Management 40: 333–339. https://doi.org/10.1016/S0378-3774(99)00007-4

Raxworthy CJ, Ananjeva N, Orlov NC (2012) Complete species inventories. In: McDiarmid RW, Foster MS, Guyer C, Gibbons JW, Chernoff N (Eds) Reptile Biodiversity: Standard Methods for Inventory and Monitoring. University of California Press, Berkeley, 209–215.

Rorabaugh JC, Lemos-Espinal JA (2016) A Field Guide to the Amphibians and Reptiles of Sonora, Mexico. ECO Herpetological Publishing and Distribution, Rodeo, New Mexico.

Ruíz-Guerrero M, Van Devender TR, Reina-Guerrero AL, Mejía-Mora P, van der Heiden AM (2015) A preliminary checklist of the vascular plant flora of La Guásima, southern Sinaloa, northwestern Mexico. Phytoneuron 63: 1–25.

Ruíz-Luna A, Berlanga-Robles CA (1999) Modifications in coverage patterns and land use around th Huizache-Caimanero lagoon system, Sinaloa, Mexico: A multi-temporal analysis using Landsat images. Estuarine Coastal an dShelf Science 49: 37–44. https://doi.org/10.1006/ecss.1999.0489

Saucedo B, Serrano JM, Jacinto-Maldonado M, Leuven RSEW, Rocha García AA, Méndez Bernal A, Gröne A, van Beurden SJ, Escobedo-Bonilla CM (2019) Pathogen risk analysis for wild amphibian populations folowing the first report of a ranavirus outbreak in farmed American Bullfrogs (*Lithobates catesbeianus*) from northern Mexico. Viruses 11: 26. https://doi.org/10.3390/v11010026

SEMARNAT [Secretaría de Medio Ambiente y Recursos Naturales] (2010) Norma Oficial Mexicana NOM-059-Ecol-2010. Protección ambiental-Especies nativas de México de flora y fauna silvestres-Categorías de riesgo y especificaciones para su inclusión, exclusión o cambio-Lista de especies en riesgo. Diario oficial (Segunda Sección, 30-dic), 77 pp. www.profepa.gob.mx/innovaportal/file/435/1/NOM_059_SEMARNAT_2010.pdf

Serrano JM, Berlanga-Robles CA, Ruiz-Luna A (2014) High amphibian diversity related to unexpected values in a biogeographic transitional area in north-western Mexico. Contributions to Zoology 83: 151–166. https://doi.org/10.1163/18759866-08302005

Shreve F (1937) Lowland vegetation of Sinaloa. Bulletin of the Torey Botanical Club, 64: 605–613. https://doi.org/10.2307/2481132

Smith HM (1941) A review of the subspecies of the indigo snake (*Drymarchon corais*). Journal of the Washington Academy of Sciences. 31: 466–481.

Smith HM, VanGelder RG (1955) New and noteworthy amphibians and reptiles from Sinaloa and Puebla, Mexico. Herpetologica 11:145–149.

Stejneger LH (1893) Annotated list of the reptiles and batrachians collected by the Death Valley Expedition in 1891, with descriptions of new species. North American Fauna, No. 7: 159–228 + 14 plates + 4 maps. https://doi.org/10.3996/nafa.7.0002

Taylor EH (1938 "1936") Notes on the herpetological fauna of the Mexican state of Sinaloa. University of Kansas Science Bulletin 24: 505–537.

Taylor EH (1940 "1939") Herpetological miscellany No. I. University of Kansas Science Bulletin 26: 489–571.

Taylor EH (1943) Herpetological novelties from Mexico. University of Kansas Science Bulletin 29: 343–361.

Torres-Sombra J, García-Salazar JA, García-Mata R, Matus-Gardea J, González-Estrada E, Pérez-Zamorano A (2013) Response of the water demand to changes in the price: A study by type of consumer in northern of Sinaloa, Mexico. Agrociencia 47: 293–307.

Van Denburgh J (1897) Reptiles from Sonora, Sinaloa and Jalisco, Mexico, with a Description of a New Species of *Sceloporus*. Proceedings of the Academy of Natural Sciences of Philadelphia 49: 460–464.

Van Devender TR, Yanes-Arvayo G, Reina-Guerrero AL, Vaenzuela-Yánez M, Montañez-Armenta MP, Silva-Kurumiya H (2013) Comparison of the tropical floras of the Sierra la Madera and the Sierra Madre Occidental, Sonora. In: Gottfried GJ, Ffolliott PF, Gebow BS, Eskew LG, Collins LC (compilers) Merging Science and Management of the Madrean Archipelago III and 7th Conference on Research and Resource Management in the Southwestern Deserts. 1–5 May 2012, Tucson, Arizona. Proceedings RMRS-P-67. Fort Collins, CO; US Department of Agriculture, Forest Service, Rocky Mountain Research Station Mexico, 240–242.

Uetz P, Hošek J (2019) The Reptile Database. http://www.reptile-database.org [accessed 24 October 2019]

Wiegmann AFA (1834) Herpetologia Mexicana, seu descriptio amphibiorum novae hispaniae, quae itineribus comitis de Sack, Ferdinandi Deppe et Chr. Guil. Schiede im Museum Zoologicum Berolinense Pervenerunt. Pars prima, saurorum species. Berlin, Lüderitz, iv + 54 pp. https://doi.org/10.5962/bhl.title.119131

Wilson LD, Johnson JD, Mata-Silva V (2013a) A conservation reassessment of the amphibians of Mexico based on the EVS measure. Amphibian & Reptile Conservation 7(1): 97–127.

Wilson LD, Mata-Silva V, Johnson JD (2013b) A conservation reassessment of the reptiles of Mexico based on the EVS measure. Amphibian & Reptile Conservation 7(1): 1–47.

Woolrich-Piña GA, Ponce Campos P, Loc-Barragán J, Ramírez-Silva JP, Mata-Silva V, Johnson JD, García- Padilla E, Wilson LD (2016) The herpetofauna of Nayarit, Mexico: composition, distribution, and conservation. Mesoamerican Herpetology 3: 376–448.

Appendix 1

Museum collections included in the VertNet.org database records of Sinaloa amphibians and reptiles that house specimens of the first record of a species in Sinaloa.

AMNH	Collection of Herpetology, Herpetology Department, American Museum of Natural History
ANSP	Academy of Natural Sciences of Philadelphia. ANSP Herpetology
CAS	Collection of Herpetology, Herpetology Department, California Academy of Sciences
CMNH	Collection of Herpetology, Amphibian and Reptile Section, Carnegie Museum of Natural History, Pittsburgh
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
MCZ	Collection of Herpetology, Museum of Comparative Zoology, Harvard University Cambridge
MNHUK	Museum of Natural History, Division of Herpetology, University of Kansas
MSUM	Michigan State University Museum. MSUM Ichthyology and Herpetology Collections
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
UAZ	Amphibians and Reptiles Collections, University of Arizona
UCM	Collection of Herpetology, University of Colorado Museum
UMNH	Natural History Museum of Utah. UMNH Reptiles and Amphibians Collection
UMMZ	Collection of Herpetology, Museum of Zoology, University of Michigan Ann Arbor
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

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Composition and Natural History of Snakes from Etá Farm region, Sete Barras, south-eastern Brazil

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Abstract

Approximately 140 snake species are known to occur in the Atlantic Forest with nearly half being endemic to this ecoregion. However, the Atlantic forest is one of the most threatened tropical ecoregions, with only 16% of its original area remaining as forest. This extensive habitat loss must have had a negative effect on its snake fauna. Indeed, 53% of the threatened snakes of Brazil occur in the Atlantic forest. Therefore, basic natural history information that can potentially contribute to the conservation of Atlantic forest snakes are urgently needed. Here the natural history of a snake assemblage at Etá Farm region, Sete Barras municipality, south-eastern Brazil is described, and a visual guide and an identification key provided that can be used by researchers and local people to identify snakes from this region. Most of the species found in the field use both open areas and forests, are primarily terrestrial, present diurnal activity, and include frogs in their diet. A higher number of enlarged follicles, eggs, and/or embryos were recorded during the warm and rainy season. Seventeen different types of defensive tactics were recorded in the species found in the field. This study provides useful information for understanding the structure of snake assemblages of the Atlantic Forest and is potentially useful for conservation assessments and for designing conservation plans.

Keywords

banana plantation, diet, habitat, peach palm plantation, rainforest, reproduction, reptiles

Introduction

Natural history information, what organisms do in their respective environments, including interactions between them (Greene 1994), contributes beyond the basic refinement of science (Greene and McDiarmid 2005) but also to our understanding of how environments function and, consequently, aids in many aspects of conservation, management, and appreciation of nature (Caughley 1994, Brooks and McLennan 2002, Dayton 2003). Despite their obvious relevance, there is still a considerable knowledge gap on the ecology and behaviour of most snake species, even in well-studied regions in the world (Greene 2005). For example, *Bothrops jararacussu* is one of the most widespread species in the Atlantic forest, yet most of its natural history data come from only a few localities of southeastern Brazil (Marques 1998, Martins et al. 2002, Hartmann et al. 2009b). Valuable natural history information is available for only a small fraction of animal species, usually those that are large or common and relatively easy to study (Greene 1994). Neotropical snakes are no exception and despite the studies published on these animals (Strüssmann and Sazima 1993, Marques 1998, Martins and Oliveira 1998, Cechin 1999, Di-Bernardo 1999, Sawaya et al. 2008, Hartmann et al. 2009ab, Pontes et al. 2009, Gaiarsa et al. 2013, Mesquita et al. 2013, Guedes et al. 2014), many species are still only known from small portions of their distributions.

The Atlantic forest of eastern Brazil harbours a very rich snake fauna, with approximately 140 species, representing 34% of the 412 species of snakes known to occur in Brazil (Costa and Bérnils 2018; Marques et al. 2019; Nogueira et al. 2019). Furthermore, almost half (45%) of the Atlantic forest snakes are endemic to these forests. However, the Atlantic forest is one of the most threatened tropical ecoregions (Myers et al. 2000), with only 16% of its original area remaining as forest (Ribeiro et al. 2009). The extensive habitat loss to which the Atlantic forest was subject in the last decades have likely had a negative effect on its snake fauna. Indeed, 53% of the threatened snakes of Brazil occur in the Atlantic forest and there is a lack of baseline data for an additional ten snake species, from this ecoregion, making the assessment of their conservation status difficult (ICMBio, 2018). Therefore, basic natural history information that can potentially contribute to the conservation of Atlantic forest snakes are urgently needed.

Here we provide basic natural history information for an Atlantic Forest snake assemblage from south-eastern Brazil. We sampled pristine along with disturbed habitats, thus assessing the ability of the Atlantic forest snakes to persist in disturbed habitats. For each species we provide primary information on habitat and micro-habitat use, time of activity, feeding habits, reproduction and defence. We also provide a short review of the natural history of each species based on our results and on previously published accounts.

Materials and methods

The primary information used in this study was obtained between April 2013 and March 2014 at the region of Etá Farm (24°19'13"S, 48°7'3"W) in the Sete Barras municipality, São Paulo state, south-eastern Brazil. The area is located within the Atlantic forest in a hillside forest formation (Joly et al. 1992). While this region shows great variation in elevation, ranging from 45 m at Etá Farm to over 800 m at the Sete Barras Operational Centre of Carlos Botelho State Park (Forlani et al. 2010), sampling for this study was carried out within the 45–80 m range (Figure 1). We searched the literature and museum databases for additional species that might occur in the Sete Barras municipality and neighbouring areas and that we could have failed to find during our fieldwork.

Phytosociological and floristic studies have shown high richness of tree and shrub species in this type of Atlantic forest formation (Mantovani 1993). In addition to forests in an advanced stage of regeneration, areas modified by agriculture (considered "open areas"), such as peach palm (*Bactris gasipaes*) and banana (*Musa* sp.) plantations, were also sampled (Figure 2).

Field data were collected by two researchers for 14 days per month, from April 2013 to March 2014, for a total sample time of 168 days. Snakes were sampled with pitfall traps with drift fences (Greenberg et al. 1994, Cechin and Martins 2000), time constrained searches (sensu Campbell and Christman 1982, Scott et al. 1989, Martins and Oliveira 1998), and accidental encounters (Martins and Oliveira 1998), the latter including snake encounters by local people (Martins and Nogueira 2012). Three main vegetation types were sampled with pitfall traps with drift fence: banana plantation

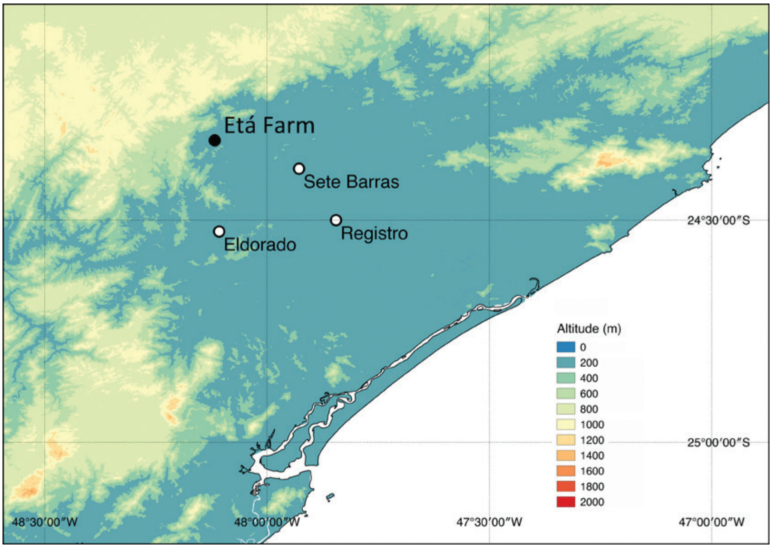

Figure 1. Topographic map of the region where the Etá Farm is located.

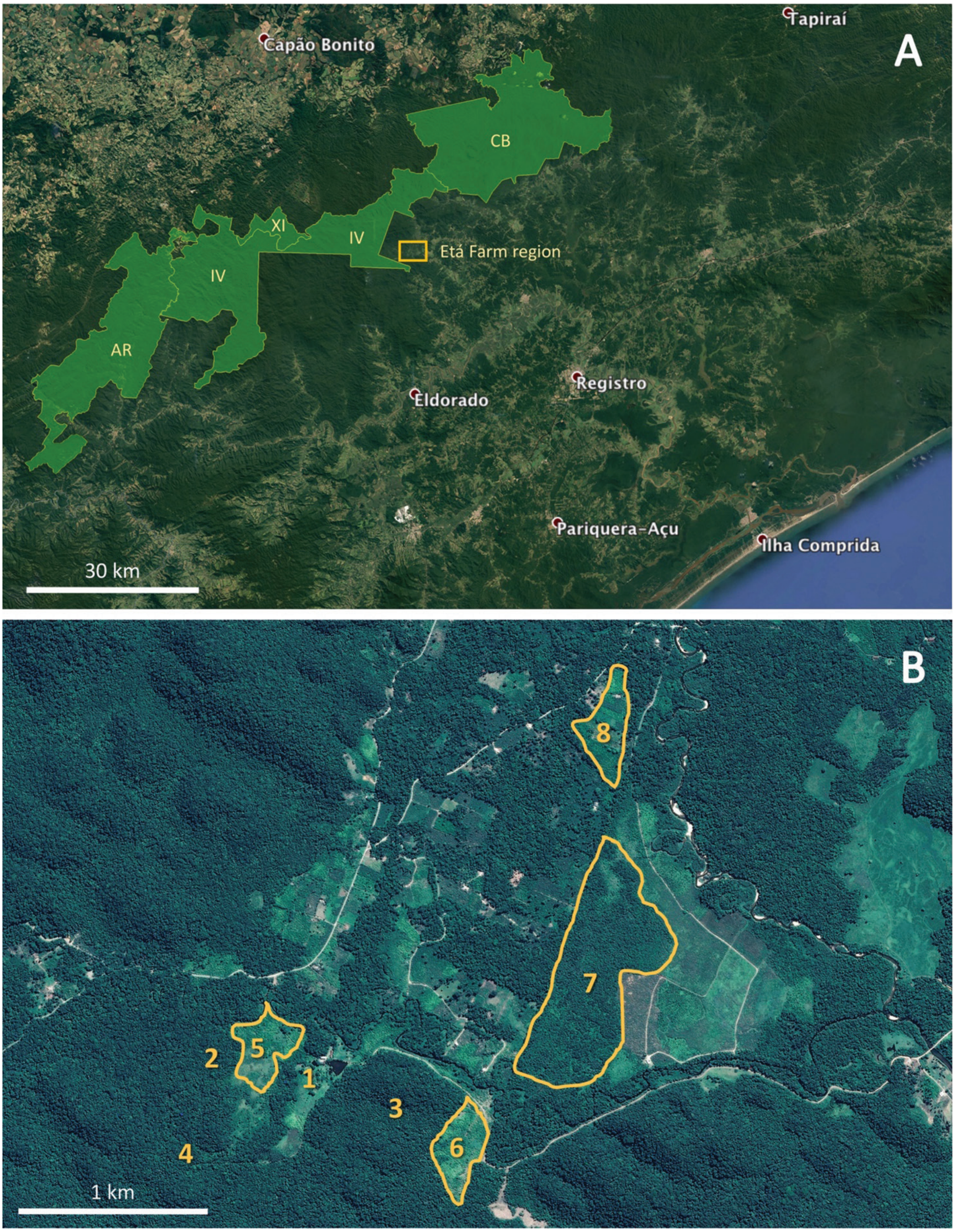

Figure 2. Satellite images (source: Google Earth) **A** the region where the study area (light orange rectangle) is located in the southern São Paulo State and the group of continuous protected areas (in light green) that encompasses most of the primary forests of this region (AR = Parque Estadual Turístico do Alto Ribeira; CB = Parque Estadual Carlos Botelho; IV = Parque Estadual Intervales; XI = Estação Ecológica de Xituê) as well as the location of the Etá Farm region (rectangle) **B** the region of the Etá Farm, Sete Barras Municipality where 1 indicates the Etá Farm administrative buildings, 2–4 indicate areas of forest, 5 and 6 indicate peach palm plantations; 7 indicates abandoned banana plantation, and 8 indicates an agricultural settlement.

(Figure 2B; site 7), peach palm plantation (Figure 2B; sites 5 and 6), and forest (Figure 2B; sites 2 and 3). Our sampling design for pitfall traps included two sampling units per vegetation type, each sampling unit comprising three Y sets (with 12 m-long branches), located 100 m from each other. Thus, we installed a total of six sampling units with a total of 18 Y sets and 72 buckets. Sampling units were located at least 500 m from each other. Each Y set had four 100 L plastic buckets (three at each branch end and one in the centre) connected by a 60 cm-high plastic fence. The buckets were perforated at the bottom to avoid accumulation of rainwater. Two additional sites (Figure 2B; sites 4 and 8) were sampled occasionally or through time constrained searches.

Habitat use was recorded through active search for individuals (made only at night), describing the habitats (e. g., open area, forest, banana plantation) and micro-habitats used by each snake (fossorial, aquatic, terrestrial or arboreal) and perch height (in case of arboreal species). To characterise micro-habitats we used only information obtained during active searches; for individuals collected with pitfall traps, only vegetation cover (forest, peach palm or banana plantation) was considered.

To describe diet, collected specimens were dissected through an incision in the ventral region. Food items were identified to the lowest possible taxonomic rank using taxonomic keys, identification guides, specimens deposited in scientific collections and help from experts. Whenever the prey came from a snake captured in a pitfall trap, this information was included, given the possibility of the snake having ingested prey that had also fallen in the trap (Cechin and Martins 2000) but which is not part of the snake's usual diet. Additional specimens of the studied species from the herpetological collection of the Butantan Institute were also dissected.

To describe reproductive condition, we recorded the length of the largest follicle, egg or embryo, and number of vitellogenic follicles (> 10 mm), eggs or embryos in every month of collection. Specimens collected in the field in the study area and specimens from the herpetological collection of the Butantan Institute were dissected for this purpose.

Behavioural descriptions are based on observations made over short periods of time (*ad libitum* and sequence samplings; Altmann 1974). Defensive behaviours were recorded when individuals were observed in the field and when handled.

Results

With a sampling effort of 168 days of fieldwork, including 558 person-hours of visual search, we found 255 individuals of 17 species of snakes (14 genera, four families) at the Etá Farm region. Additionally, we included *Corallus cropanii* to our study because it was found previously by other researchers in our study area (Machado Filho et al. 2011). Species richness was similar between forests (13 species) and disturbed areas (banana plantation, peach palm plantation, roads, pastures, and around houses; 16 species; Table 1).

Besides the 17 species we found during our fieldwork at Fazenda Etá region and *C. cropanii* (Machado Filho et al. 2011), eight additional species are known to occur in the Sete Barras municipality: *Chironius bicarinatus*, *Chironius foveatus*, *Clelia plumbea*,

Table 1. Number of individual snakes found in the Etá Farm region, Sete Barras, SP, Brazil, in forests and disturbed areas, considering all sampling methods. Forest includes forests and forest borders; Disturbed includes banana plantations, peach palm plantations, and other disturbed areas (roads, pastures, areas around houses); *N* = number of specimens recorded. The asterisk indicates a species that was found by other researchers in our study area (Machado-Filho et al. 2011).

	Forest	**Disturbed**	***N***
Boidae			
*Corallus cropanii**		1	1
Colubridae			
Chironius exoletus		1	1
Chironius fuscus	1	7	8
Chironius laevicollis	3	1	4
Spilotes pullatus		15	15
Dipsadidae			
Dipsas neuwiedii		25	25
Echinanthera cephalostriata	2	1	3
Erythrolamprus aesculapii	2	3	5
Erythrolamprus miliaris	22	53	75
Helicops carinicaudus	7	6	13
Oxyrhopus clathratus	3	9	12
Sordellina punctata	5	2	7
Taeniophallus bilineatus	2		2
Tomodon dorsatus		3	3
Xenodon neuwiedii	2	4	6
Elapidae			
Micrurus corallinus	1	5	6
Viperidae			
Bothrops jararaca	4	19	23
Bothrops jararacussu	9	38	47
TOTAL	**63**	**193**	**256**

Dipsas albifrons, *D. alternans*, *Echinantera undulata*, *Tropidodryas serra*, and *Tropidophis paucisquamis* (Nogueira et al., 2019). Furthermore, eight additional species occur in neighbouring regions (Cananéia Island, Iguape, Registro, and Pariquera-Açu) and thus could also occur in the Fazenda Etá region: *Corallus hortulanus*, *Dipsas indica*, *D. variegata*, *Echinanthera cynopleura*, *Imantodes cenchoa*, *Siphlophis pulcher*, *Taeniophallus persimilis, and Thamnodynastes nattereri* (Sena 2007; Pereira et al., 2007; Nogueira et al, 2019). We included all the species above in the figures depicting the snakes found in the Etá Farm region (Figs 3–7), as well as in the identification key here provided, because they can be used by researchers and local people to identify snakes they find in this region.

General natural history patterns

Among the species we found in the field, most used forested areas (> 70% of species), were primarily terrestrial (70%), showed diurnal activity (> 58%), and included frogs in their diet (> 50%; information supplemented with data from the literature). Only those which consumed endothermic prey and *Dipsas neuwiedi* showed nocturnal activity. However, there was a relatively high percentage (30%) of semi-arboreal species, observed almost exclusively in open areas or forest edges, all anuran specialists (except for *Spilotes pullatus*) and belonging to the family Colubridae.

In addition to species that were semi-arboreal and anuran specialists, the mollusc-specialist species *D. neuwiedi* and *T. dorsatus* were also found exclusively in open areas. Only *T. bilineatus* proved to be the most limited to the forest habitat (*N* = 2), particularly to a cryptozoic micro-habitat (see Habitat Use of *Taeniophallus bilineatus* under Natural history accounts). The species *E. miliaris* and *B. jararacussu* showed the broadest spectrum of the assemblage in terms of resource use, as both widely used open and forested areas and included 3 and 4 different types of prey in their diet, respectively.

The viperids *B. jararaca* and *B. jararacussu* and the dipsadids *D. neuwiedii* and *O. clathratus* were the species most commonly found in disturbed areas such as plantations, around houses and even inside houses. Particularly for *O. clathratus*, 75% of observations occurred in disturbed habitats; the remaining took place in the forest.

Among the snake specimens whose stomach contents were analysed, 82 individuals, belonging to eleven different species, had prey in their digestive tracts. Of those, most have ingested frogs (61%), followed by mammals (18.3%), molluscs (11%), snakes (3.7%), fishes (2.4%), non-mollusc invertebrates (leech and centipede) (2.4%), and lizards (1.2%) (Table 2). The assemblage showed a great number of species whose bulk of the diet consisted of, or included, frogs, especially leptodactylids (more than 70% of anuran records), the group that was most captured in pitfall traps in the region (see Fiorillo et al. 2018). The second item most found was small mammals (more than 18%), of which rodents (more than 80% of the mammals), particularly from the tribe Akodontini (> 40% of the rodents) were the most frequent. Almost all small mammals recorded were consumed by vipers; only two cases were reported for species from other families (*S. pullatus* and *O. clathratus*).

Although, in qualitative terms, *E. miliaris* and *B. jararacussu* showed a greater diversity of items in their diets, they may be considered specialists in frogs (> 95% of the diet of *E. miliaris*) and small mammals (> 58% of the diet of *B. jararacussu*), respectively. However, most of the records obtained for *E. miliaris* came from individuals caught in pitfall traps (> 87% of cases). Hence, part of the frogs may have been opportunistically consumed by this species (the finding of 14 specimens of *E. miliaris* captured in pitfall traps, that ingested *P. spiniger*, supports this assumption). Only four individuals of this species were captured by other capture methods, one of which had consumed a fish.

Of the specimens examined, 28 were reproductive females containing vitellogenic follicles, eggs or embryos. In the three families, as with activity, larger follicles were found during the Austral Spring, with the largest vitellogenic follicles, as well as eggs and embryos, occurring from September to October, except for one specimen of *Erythrolamprus aesculapii* that had vitellogenic follicles during the month of July (Austral Winter). Over the sampling period, only one single mating behaviour was observed for *S. pullatus*, in September (see Natural history accounts).

A total of 17 different defensive tactics was recorded for the assemblage studied, with some variations and combinations of them (Table 3). Most seem to be aimed at

Table 2. Food items found in the digestive tract of snakes from the region of Etá Farm region, Sete Barras, SP, Brazil. *N* = number of snakes with respective stomach or intestinal contents, or observation.

Family/Species	*N*	Stomach contents
Colubridae		
Chironius laevicollis	2[1]	*Leptodactylus latrans* (Anura, Leptodactylidae)[1]
Spilotes pullatus	1[1]	Unidentified rodent hair
Dipsadidae		
Dipsas neuwiedi	2[1]	*Limax* cf. *flavus* (Molusca, Limacidae)[1]
	1[1]	*Meghimatium pictum* (Molusca, Philomycidae)[1]
	2[1]	Unidentified Molusca[1]
	4[1]	*Phyllocaulis* sp. (Molusca, Philomycidae)[1]
Erythrolamprus aesculapii	1[1]	Snake scales
	1[1]	*Sibynomorphus neuwiedi* (Serpentes, Dipsadidae)[1]
Erythrolamprus miliaris	1[1];1[2]	Unidentified frog fragments[2]
	1[1];5[2]	Fragments of *Leptodactylus* sp. (Anura, Leptodactylidae)[1,2]
	2[2]	Fragments of *Rhinella* sp. (Anura, Leptodactylidae)[2]
	3[2]	*Leptodactylus latrans* (Anura, Leptodactylidae)[2]
	1[1];4[2]	*Leptodactylus notoaktites* (Anura, Leptodactylidae)[1,2]
	1[1]; 14[2]	*Physalaemus spiniger* (Anura, Leptodactylidae)[1, 2]
	1[2]	*Placosoma glabellum* (Lacertilia, Gymnophtalmidae)[2]
	2[2]	*Rhinella hoogmoedi* (Anura, Leptodactylidae)[2]
	2[2]	*Rhinella icterica* (Anura, Bufonidae)[2]
	1[2]	*Rhinella ornata* (Anura, Bufonidae)[2]
	1[1]	*Synbranchus marmoratus* (Synbranchiformes, Synbranchidae)[1]
Helicops carinicaudus	1[1]	*Characidium* sp. (Characiformes, Crenuchidae)
	1[1]	Unidentified frog fragments
	1[1]	*Leptodactylus latrans* (Anura, Leptodactylidae)[1]
Oxyrhopus clathratus	1[2]	*Monodelphis americana* (Didelphimorphia, Didelphidae)[2]
Sordellina punctata	1[1]	Leech (Annelida, Hirudinea)[1]
Xenodon neuwiedii	1[1]	Unidentified frog fragments
	1[1]	Fragments of *Rhinella hoogmoedi* (Anura, Bufonidae)[1]
	1[2]	*Rhinella icterica* (Anura, Bufonidae) [2]
Viperidae		
Bothrops jararaca	1[1]	Akodontini (Rodentia)[1]
	2[1]	Unidentified rodent hair
Bothrops jararacussu	1[1]	*Akodon* sp. (Rodentia, Cricetidae)[1]
	2[1]	Akodontini (Rodentia, Cricetidae)[1]
	1[1]	*Brucepattersonius* sp. (Rodentia, Cricetidae)[1]
	1[1]	*Didelphis* cf. *aurita* (Marsupialia, Didelphidae)[1]
	1[1]	Fragments of *Leptodactylus* sp. (Anura, Leptodactylidae)[1]
	3[1]	Fragments of *Leptodactylus latrans* (Anura, Leptodactylidae)[1]
	1[1]	Fragments of Hylidae (Anura, Leptodactylidae)[1]
	1[1]	Unidentified mammal fragments
	1[1]	Centipede (Scolopendromorpha, Scolopendridae)[1]
	1[1]	*Oligoryzomys* sp. (Rodentia, Cricetidae)[1]
	3[1]	Unidentified rodent
	1[1]	*Sordellina punctata* (Serpentes Dipsadidae)[1]

[1]Individuals captured in active searches or by others. [2] Individuals captured in pitfall traps.

visually oriented predators (being "flatten body" most frequent among them, used by 70% of the species), but cloacal discharge had the same frequency (used by 70% of the species in the region, considering field observations and data from the literature).

Table 3. Defensive tactics of snakes from the Etá Farm region, Sete Barras, SP, Brazil. CB = compress body while raising head; CD = cloacal discharge; SC = S-coil; DM = display buccal mucosa; DV = display ventral posterior region; EM = perform erratic movements; FB = flatten body; HH = hide head; IG = inflate gular region; MI = mimicry; OM = open mouth; RB = rotate body; RH = raise head; ST = strike; TD = tail display; TH = triangulate head; VT = vibrate tail. The numbers indicate field observations and an "X" indicates data from the literature (Hoge 1953, Marques and Sazima 2004, Martins et al. 2008, Menezes et al. 2015).

Species	CB	CD	SC	DM	DV	EM	FB	HH	IG	MI	OM	RB	RH	ST	TD	TH	VT
Chironius exoletus		X	1						X		1			1			
Chironius fuscus		X	X						X		X	X	X	2			X
Chironius laevicollis		X	X						X		X		X	X			X
Spilotes pullatus		X	X						10		1		X	4			4
Dipsas neuwiedi		4	X					1		X			X			19	
Echinanthera cephalostriata		X					X						1				
Erythrolamprus aesculapii	X					X	X	X		X					X		
Erythrolamprus miliaris	X	20					2					5				3	
Helicops carinicaudus		X					X	X						4			
Oxyrhopus clathratus						X	1	X		X							
Sordellina punctata		2					X										
Taeniophallus bilineatus		X					X										
Tomodon dorsatus			X	X			X	X					X	X			
Xenodon neuwiedii	X		X				1			X			X	1		X	
Micrurus corallinus	X				1	X	X	X									
Bothrops jararaca		X					X							4			6
Bothrops jararacussu		X					X							2			5

Another defence shown by many species was cryptic colouration (82%), which was common in diurnal species (58% of the assemblage). In contrast, only three species showed aposematic or mimetic colouration (*M. corallinus* and their supposed mimics *E. aesculapii* and *O. clathratus*).

Natural history accounts

Boidae Gray, 1825

Corallus cropanii (Hoge, 1953)

This large species (maximum SVL = 1510 mm; Marques et al. 2019) is rare in the Etá Farm region. Although not sampled during our study, an individual of *C. cropanii* was found by Machado Filho et al. (2011) in the agricultural settlement north of the Etá Farm (Fig. 2). The holotype was found on vegetation at 1.5 m above the ground; in captivity, it remained perched on branches for most of the time (Marques and Cavalheiro 1998). The only known food content is the land opossum, *Metachirus nudicaudatus* (Didelphimorphia, Didelphidae; Marques and Cavalheiro 1998). This is a viviparous species (Marques et al. 2019), but there is no detailed information available on its reproduction. It may raise its head while opening its mouth (Hoge 1953).

Colubridae (Ooppel, 1811)

Chironius exoletus (Linnaeus, 1758)

This is an aglyphous species of medium size (maximum SVL = 790 mm; *N* = 1). Only one individual was found, in the peach palm plantation, on the vegetation at 0.5 m above the ground, during the day, in November. The available information indicates that it is semi-arboreal and diurnal (França and Araújo 2006, Martins et al. 2008, this study), but forage mainly on the forest ground where it feeds primarily on hylid frogs (Sazima 1992, Dixon et al. 1993, França and Araújo 2006, Rodrigues 2008; Marques and Sazima 2004; 2019). Its fecundity ranges from 4–12 eggs (Dixon et al. 1993, Bernarde and Abe 2006). When handled, the individual found opened its mouth, struck, and raised its head and formed an S-coil with the anterior part of the body (Table 3). It may also perform gular inflation, lateral fattening and cloacal discharge (Martins et al. 2008, Marques et al. 2019).

Chironius fuscus Linnaeus, 1758

This is an aglyphous species of medium size (maximum SVL = 919 mm; *N* = 8). It was found crossing an unpaved road, always near the forest edge (*N* = 6), and on a trail in the forest near the abandoned banana plantation, lying coiled up on a tree at 1.5 m above the ground (*N* = 1). One juvenile was found while crossing a paved road close to the urban area of Sete Barras, during the day. The available information indicates that it is diurnal and semi-arboreal, but forage mainly on the ground of the forests (Martins and Oliveira 1998, Marques and Sazima 2004, Martins et al. 2008, this study) where it feeds primarily on leptodactylid frogs (Strüssmann and Sazima 1993, Martins and Oliveira 1998, Marques and Sazima 2004). At Etá farm, it was found during most of the year, with a higher incidence of juveniles from April to June. One female had six vitellogenic follicles in May. In the Amazon region, females were collected with 3–8 eggs in the oviducts, from March–July and in October (Dixon and Soini 1986, Dixon et al. 1993, Martins and Oliveira 1998). The handled individuals struck (*N* = 2; Table 3). This snake also opens its mouth, raises its head, and forms an S-coil with the anterior part of its body, flattening and inflating the gular region in frontal display, performs cloacal discharge, rotates its body and vibrates its tail (Beebe 1946, Dixon and Soini 1986, Martins et al. 2008, Marques and Sazima 2004, Marques et al. 2019).

Chironius laevicollis (Wied, 1824)

This is an aglyphous species of large size (maximum SVL = 1650 mm; *N* = 4). One individual was found on the ground, during the day, moving through the peach palm plantation; another was foraging on the forest floor at the margins of the Etá River during the day. Before being captured, the individual found on the trail quickly climbed a tree to a height of approximately 3 m. One individual was observed in a shallow pond at the edge of the forest, "yawning" as if it had just ingested something, shortly

Figure 3. A *Corallus cropanii* **B** *C. hortulanus* **C** *Chironius bicarinatus* (photo: Arthur Abegg) **D** *C. exoletus* **E** *C. foveatus* **F** *C. fuscus* **G** *C. laevicollis* **H** *Spilotes pullatus*.

before swimming away, also during the day. The available information indicates that it is diurnal and terrestrial, being arboreal during the juvenile stage (Dixon et al. 1993, Marques and Sazima 2003, Martins et al. 2008, this study). In the digestive tracts of the examined specimens we found frogs of the species *Leptodactylus latrans* (Table 2), one of which had been swallowed headfirst. Previous studies also indicate that the species feeds on frogs (Dixon et al. 1993, Marques 1998). At the Etá farm, individuals were found in January, May, June and December; one female had 38 primary follicles in May and another had ten secondary follicles in January. Previous observations indicate that it has a fecundity of 10–14 eggs and has a seasonal reproductive cycle (vitellogenic follicles in August–December and oviductal eggs in October–November; Costa et al. 2005). It may open its mouth, perform a frontal display by raising its head, forming an S-coil with the anterior part of its body, and inflating the gular region, strike, perform cloacal discharge and vibrate the tail (Marques et al. 2019, Martins et al. 2008; Table 3).

***Spilotes pullatus* (Linnaeus, 1758)**

This is an aglyphous species of large size (maximum SVL = 1830 mm; *N* = 15). It was found in a pile of wood next to a house in an operating banana plantation (*N* = 4), in an abandoned banana plantation (*N* = 1), in peach palm plantations (*N* = 2), on the edge of the forest (*N* = 1), in a pasture (*N* = 1) and crossing a paved road in areas surrounded by forest and pasture (*N* = 2). Three run-over individuals were collected on an unpaved road near the edge of forest. The available information indicates that it is semi-arboreal and diurnal (Vanzolini et al. 1980, Marques and Sazima 2004, Bernarde and Abe 2006, this study). We found four rodent nestlings, all ingested headfirst, in the stomach of a specimen (Table 2). Previous studies with specimens from the Atlantic forest revealed that this snake feeds mainly on very small mammals and nestling birds (Marques et al. 2014). At Etá farm, one mating pair was found in September; two females had eight and 11 eggs in their oviducts, in September. Most adult individuals were observed in August and September (*N* = 7), while juveniles were observed in February (*N* = 3). Marques et al. (2014) reported oviposition for various localities in the Atlantic forest, restricted to the onset of the rainy season (October–November) and Bernarde and Abe (2006) observed juveniles in the same period in southwestern Amazon. Previous reports indicate that it lays 5–12 eggs (Amaral 1930, Hauzman and Costa 2005, Marques et al. 2014). The temperament of the individuals found varied greatly, from very docile to extremely aggressive. When handled, the individuals found opened the mouth (*N* = 1), vibrated the tail (*N* = 4), inflated the gular region (*N* = 10) and struck (*N* = 4) (Table 3). Previous studies indicate that it may also perform cloacal discharge and frontal displays by raising the head and forming an S-coil with the anterior part of its body (Martins et al. 2008, Marques et al. 2019).

Dipsadidae Bonaparte 1838

***Dipsas neuwiedi* (Ihering, 1911)**

This is an aglyphous species of medium size (maximum SVL = 643 mm; *N* = 31). It was found mostly in the peach palm plantation (*N* = 15), with only one individual captured in a pitfall trap. It was found also around the houses (*N* = 5) and crossing the unpaved road at night (*N* = 5). One individual was found resting under the lid of one of the pitfall trap buckets during the day. We have no information on habitat use for the other five individuals. The available information indicates that it is nocturnal and semi-arboreal (Freitas 1999, Oliveira 2001, this study). Of the 31 specimens examined, ten had molluscs in their digestive tract (Table 2), most of them of the genus *Phyllocaulis* (*N* = 4), endemic to South America. In two cases the snakes had eaten *Limax* cf. *flavus* snails, an exotic European species, while in another, a *Meghimatium pictum* slug, an exotic Chinese species, both considered invasive. The available information indicates that it is a mollusc specialist (Freitas 1999, Oliveira 2001, Marques and Sazima 2004, this study). It was found throughout the year and one female had four oviductal eggs in March. The available information indicates that it has a seasonal reproductive cycle, with vitellogenesis occurring between July and December, and oviposition between August and February (Pizzatto et al. 2008). Barbo et al. (2011) reported a female with nine eggs. When handled, the individuals found at the Etá Farm performed cloacal discharge (*N* = 4), hid the head within the coiled body (*N* = 1), and triangulated the head (*N* = 19). Information available in the literature indicates that, besides being a supposed mimic of vipers such as *B. jararaca*, it may also raise the head and form an S-coil with the anterior part of the body (Martins et al. 2008) (Table 3).

Echinanthera cephalostriata **Di-Bernardo, 1996**

This is an aglyphous species of small size (maximum SVL = 399 mm; *N* = 3). Individuals were found crossing the road near forest and pasture areas during the day (*N* = 2), and moving in the leaf litter in the forest at night (*N* = 1). In a study at Serra do Medanha, Rio de Janeiro (Pontes et al. 2008), the species was found exclusively in forests. The available information indicates that it is diurnal, terrestrial, and cryptozoic (Martins et al. 2008, Barbo et. al. 2011, Hartmann et al. 2011, this study), and feeds on frogs (Marques et al. 2019, Marques et al. 2009, Forlani et al. 2010). At the Etá farm, it was found during the months of July, November and December. One female collected in the municipality of Iguape (50 km from the Etá Farm) had eight vitellogenic follicles in November (data provided by staff from the Butantan Institute). When handled, one of the individuals found raised the anterior part of the body (Table 3). It may also flatten its body and perform cloacal discharge (Martins et al. 2008, Marques et al. 2019).

Erythrolamprus aesculapii **(Linnaeus, 1766)**

This is an opistoglyphous species of medium size (maximum SVL = 827 mm; *N* = 5). Four individuals were found on an unpaved road: two moving near a pasture, one near an operating banana plantation and one crossing an unpaved road near the forest edge, all during the day. The last individual was found inside the forest. The available information indicates that it is terrestrial, cryptozoic and primarily diurnal (Bernarde

Figure 4. A *Clelia plumbea* **B** *Dipsas albifrons* **C** *D. alternans* (photo: Arthur Abegg) **D** *D. indica petersi* **E** *D. neuwiedi* **F** *D. variegata* **G** *Echinanthera cephalostriata* **H** *E. cyanopleura* (photograph Marcos Di-Bernardo).

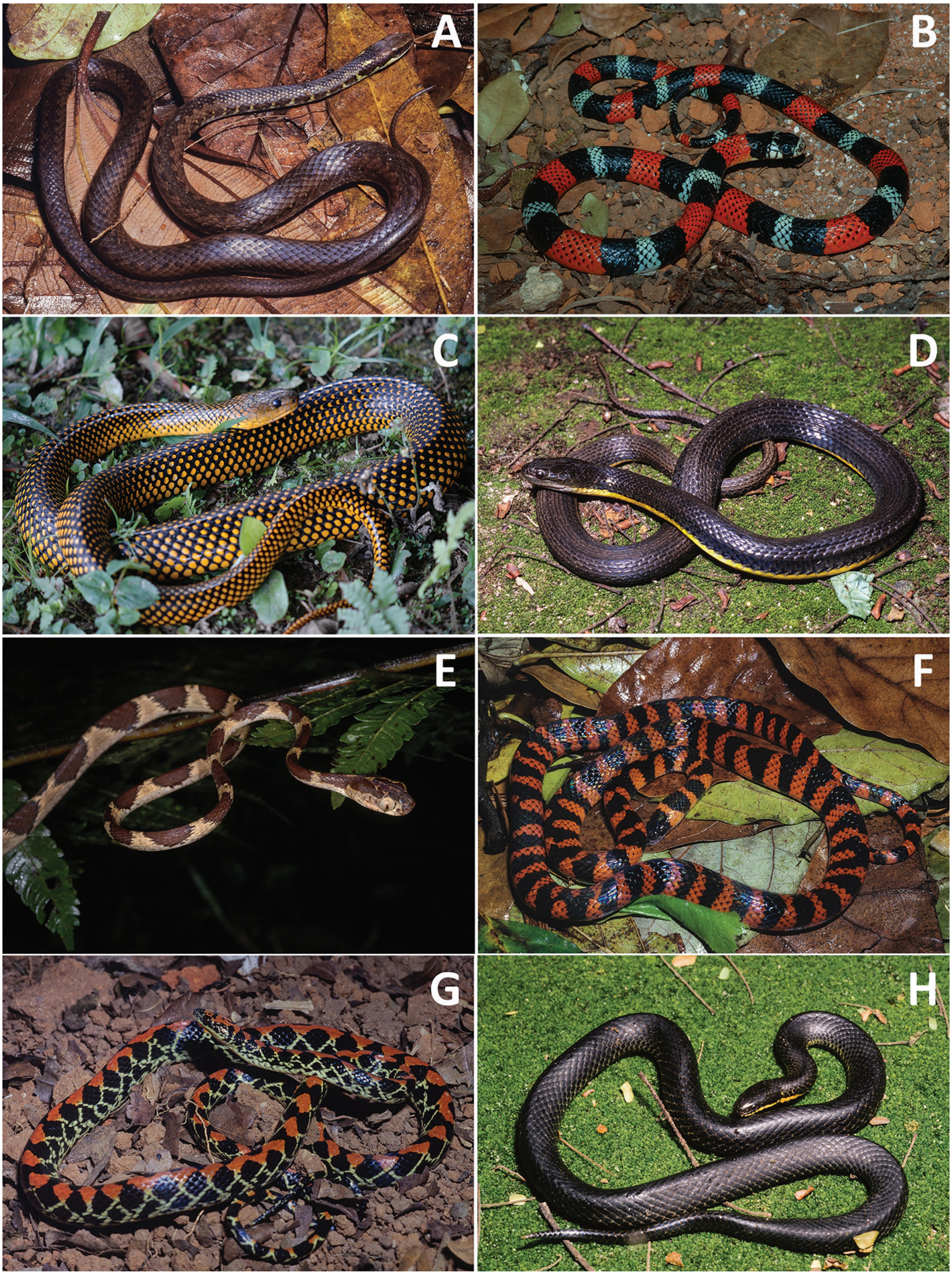

Figure 5. A *Echinanthera undulata* **B** *Erythrolapmprus aesculapii* **C** *E. miliaris* **D** *Helicops carinicaudus* **E** *Imantodes cenchoa* (photo: Ricardo J. Sawaya) **F** *Oxyrhopus clathratus* **G** *Siphlophis pulcher* **H** *Sordellina punctata*.

and Abe 2006, França and Araujo 2006, Martins et al. 2008, this study). In the digestive tract of the examined specimens we found an individual of *D. neuwiedi*, swallowed headfirst in one specimen, and snake scales in another one (Table 2). It feeds primarily on other snakes, but juveniles also feed on very small lizards (Martins and Oliveira 1998, Bernarde and Abe 2006, França and Araujo 2006, this study). At the Etá Farm, a female had two vitellogenic follicles and two juveniles were found in June. The available information indicates that it has a fecundity of 3–8 eggs and a continuous reproductive cycle, with vitellogenesis occurring throughout the year (Marques 1996a, Marques and Sazima 2004). This snake is a supposed mimic of *M. corallinus*. Besides the similarity of the colour pattern, it flattens the body, hides the head, performs erratic movements, and raises the curled tail as in *M. corallinus*.

***Erythrolamprus miliaris* Linnaeus, 1758**

This is an aglyphous species of medium size (maximum SVL = 1000 mm; *N* = 74). It was found in all sampled vegetation types and captured, in most cases, in pitfall traps (17 in the abandoned banana plantation, 22 in forest and 23 in the peach palm plantation); it was also found in other disturbed areas (*N* = 13). When found in the traps, all individuals submerged into the water accumulated in the buckets. Most individuals were seen in the abandoned banana plantation, moving or resting in the undergrowth (*N* = 4), or foraging at the edge of flooded vegetation (*N* = 1); in the forest, moving on the ground or on the leaf litter (*N* = 2); and, in the peach palm plantation, in water puddles (*N* = 2) or undergrowth (*N* = 1). In visual searches and occasional encounters, individuals were also found at the edge of the forest (*N* = 1), in pasture areas (*N* = 3), in a swamp (*N* = 1), and around houses (*N* = 2). Some individuals were captured on the unpaved road, always near flooded areas (*N* = 3) and one adult individual was found in a puddle in an open area near the forest edge. Two juveniles were captured in very disturbed habitats, one in the sink in a house at 12:00 h and another in an operating banana plantation, moving over rocks at 15:30 h. Additionally, four individuals were found on the unpaved road, one crossing it near a swamp during the day, and another run over by a car near the peach palm plantation at 06:00 h. Observations of individuals moving were always in daytime. The available information indicates that it is semi-aquatic and both diurnal and nocturnal (Sazima and Manzini 1995, Yanosky et al. 1996, Martins et al. 2008, Torello and Marques 2017, this study). More than 90% (*N* = 38) of specimens whose digestive tract contents were analysed contained frogs (Table 2). One snake captured in a small homemade water tank contained a specimen of *Synbranchus marmoratus* in its digestive tract, swallowed by the tail, while another snake, captured in a pitfall trap, had a specimen of *Placosoma glabellum*, also ingested by the tail (Table 2). The available information indicates that it feeds mainly on amphibians, but also on fish, tadpoles, amphisbaenians and lizards (Achaval and Olmos 1997, Carreira 2002, Marques and Sazima 2004, Toledo et al. 2007, this study). At the Etá Farm it was found throughout the year, with a higher incidence in hot and rainy months. Two females showed 5–12 vitellogenic follicles from April to October, and one female had 5 oviductal eggs in October. Juveniles (< 400 mm; *N* = 36) were mainly observed during the rainy season. Pizzatto and Marques (2006) reported different types of reproductive cycle for this species in different regions of the Atlantic Forest: a continuous reproductive cycle on the coast at the northern parts of its distribution (southern Bahia state), and a seasonal one in the southern regions, both in the interior and in coastal regions (São Paulo and Paraná states), with vitellogenesis and oviposition from September to February, and births at the end of the rainy season. It has a fecundity of 5–17 eggs and reaches sexual maturity at 12 months of age, at the earliest (Vitt 1992, Achaval and Olmos 1997, Pizzatto and Marques 2006, this study). When handled, the individuals found at the Etá Farm flattened (*N* = 2) or rotated (*N* = 5) the body, raised the head while flattening the body (*N* = 2; see Menezes et al. 2015), performed cloacal discharge (*N* = 20), and triangulated the head (*N* = 3), as previously reported in the literature (Martins et al. 2008, Marques et al. 2019) (Table 3).

Helicops carinicaudus **(Wied & Neuwied, 1825)**

This is an aglyphous species of medium size (maximum SVL = 623 mm; *N* = 12). Thirteen individuals were found in the field; of those, three in the peach palm plantation, with one individual captured in a pitfall trap, and the other three in a stream at the edge of forest, in the water, all apparently active in late afternoon. Three individuals were captured on the unpaved road, all moving during the day. The other captured individuals (*N* = 7) moved across floodplains on the edge of the forest, also in late afternoon. Literature records of activity were made during both day and night (Marques and Sazima 2004, Hartmann et al. 2009b). Of the specimens examined, three had stomach contents: two of them had frogs and the other had a fish (*Characidium* sp.; Table 2). The available information indicates that the diet of this species consists mainly of fish, although it may also capture frogs (mainly leptodactylids; Albolea 1998, Marques and Sazima 2004, this study). Individuals of the species were found mainly between August and November. One female had one vitellogenic follicle in August, while two others had 11 and 13 in October and November, respectively. Two juveniles (< 350 mm) were found in March and August. The available information indicates that it has a seasonal reproduction, with vitellogenesis occurring from September to December, embryos from November to March, and juvenile recruitment between February April in Atlantic forest regions (Marques 1998, Nogueira and Marques 1998, this study). Fecundity varies between 7 to 26 embryos (Nogueira and Marques 1998). When handled, individuals found at the Etá Farm struck (4) and bit (1). Previous observations indicate that it may also flatten the body, hide the head, and perform cloacal discharge (Marques et al. 2019) (Table 3).

Oxyrhopus clathratus **Duméril, Bibron & Duméril, 1854**

This is an opisthoglyphous species of medium size (maximum SVL = 710 mm; *N* = 12). It was found mainly around houses trying to climb walls at dusk (*N* = 6), run over on the unpaved road next to the forest edge (*N* = 2), and moving on the ground in the forest at night (*N* = 1). One adult male was caught while crossing the unpaved road near the edge of forest at 05:30 h. Three individuals were captured in other disturbed habitats. The available information indicates that it is terrestrial and both diurnal and nocturnal (Hartmann and Giasson 2008, Martins et al. 2008, Barbo et al. 2011; this study). One individual regurgitated a marsupial (*Monodelphis americana*) (Table 2), inside one of the pitfall traps. The available information indicates that it feeds mainly on mammals, but juveniles feed primarily on lizards (Morato 2005, Hartmann et al. 2009b, Alencar 2010, Gaiarsa et al. 2013, this study). Most individuals found at the Etá Farm were juveniles (< 500 mm), found between June and September. One female collected in the municipality of Cananéia (78 km from the Etá Farm) had 17 vitellogenic follicles in April (data provided by the staff of Butantan Institute). The available information indicates that reproduction is seasonal, with the reproductive peak occurring at the onset of the rainy season in the Atlantic forest (Marques and SaziMa 2004); fecundity ranges from four to 16 eggs (Gaiarsa et al. 2013). When handled, one of the individuals found thrashed the body. This species is a supposed imperfect mimic of *Micrurus* spp. and the defensive behaviour also includes hiding the head and making erratic movements (Martins et al. 2008, Marques et al. 2019) (Table 3).

Sordellina punctata (Peters, 1880)

This is an aglyphous species of small size (maximum SVL = 461 mm; *N* = 7). It was captured in a pitfall trap in the forest (*N* = 1), crossing an unpaved road near the margins of the Etá River (*N* = 4), and in a pasture area (*N* = 1), at dusk (*N* = 3) and at night (*N* = 1). One individual was captured in another disturbed habitat. One individual had been ingested by an individual of *B. jararacussu* at the edge of the forest, at night. The available information indicates that this is a semi-aquatic, primarily diurnal species (Marques et al. 2019, Pereira et al. 2007, Marques et al. 2009, this study). A leech was found in the digestive tract of one specimen from the Etá Farm (Table 2). The available information indicates that it feeds primarily on Oligochaetes (earthworms and leeches) and eventually on caecilians (Proctor 1923, Marques 1996c, Marques et al. 2009, this study). At the Etá Farm, it was found active mainly in the hotter and rainier months, except for one individual moving across the unpaved road in June. Data obtained from preserved snakes indicate that it has a seasonal reproductive cycle (Marques, 2001). When handled, two of the individuals found performed cloacal discharge. Information available in the literature indicates that it may also flatten the body (Marques et al. 2019).

Taeniophallus bilineatus (Fischer, 1885)

This is an aglyphous species of small size (maximum SVL = 258 mm; *N* = 2). Two individuals were found, one captured in a pitfall trap in the forest, the other moving along the forest edge in the morning. The available information indicates that it is terrestrial and diurnal (Marques et al. 2019, Hartmann et al. 2009b, Forlani et al. 2010, this study). The second individual found was in a forest in July. It feeds on frogs and lizards (Di-Bernardo and Lema 1990, Marques and Sazima 2004). Apparently, it has a seasonal reproductive cycle (Marques and Sazima 2004). It may flatten the body and perform cloacal discharge (Marques et al. 2019) (Table 3).

Tomodon dorsatus Duméril, Bibron & Duméril, 1854

This is an opisthoglyphous species of small–medium size (maximum SVL = 540 mm, *N* = 3). One adult female was found in July around a house, one adult male was found on the unpaved road in December and another adult male was found run-over near the peach palm plantation in January. The available information indicates that it is terrestrial, cryptozoic and diurnal (Marques and Sazima 2004, Martins et al. 2008, Araujo et al. 2010). It feeds on molluscs (Marques et al. 2019) and some authors have suggested that it may show aggregation, perhaps related to food availability (molluscs; Bizerra 1998, Franco et al. 2006). One female collected in the municipality of Itariri (82 km from Etá Farm) had 13 vitellogenic follicles in November (data provided by the staff of Butantan Institute). The available information indicates that it has a seasonal reproductive cycle, with vitellogenesis occurring mainly by the onset of the rainy season, embryos throughout the rainy season and litter size ranging from 4 to 26 (Bizerra et al. 2005, Barbo et al. 2011). It may flatten the body, strike, raise the head and form an S-coil with the anterior part of the body, hide its head and display the buccal mucosa (Martins et al. 2008, Marques et al. 2019) (Table 3).

Xenodon neuwiedii Günther, 1863

This is an aglyphous species of medium size (maximum SVL = 555 mm; *N* = 6). It was captured in a pitfall trap in the forest (*N* = 1). One juvenile was captured as it moved through the leaf litter during the day, at 08:20 h, and one adult male was captured while crossing an unpaved road at 10:50 h. One individual was found on the peach palm plantation and another on an unpaved road, near a pasture area, during the day. The last individual was caught in unpaved road close to disturbed areas. The available information indicates that it is diurnal and terrestrial (Hartmann et al. 2009b, Forlani et al. 2010, this study). Of the specimens that had their digestive tracts examined, one had the remains of frogs: one *Rhinella icterica* and the legs of a *R. hoogmoedi* (Table 2). The available information indicates that it feeds mainly on frogs (mainly *Rhinella* spp.), lizards being an occasional prey (Silva and Rodrigues 2001, Marques and Sazima 2004, Hartmann et al. 2009b, Costa et al. 2012, this study). Most individuals found at the Etá Farm were juveniles (except for one adult male) and were found between November and December, except for one juvenile found in May. The available information indicates that it reproduces throughout the year (Jordão 1996, Condez et al. 2009) and its fecundity can reach 14 eggs (Hartmann et al. 2009a). When handled, individuals found at the Etá Farm flattened the body (*N* = 1) or struck (*N* = 1). The available information indicates that, besides being a supposed mimic of vipers such as *B. jararaca*, it may also triangulate the head, raise the head and form an S-coil with the

Figure 6. A *Taeniophallus bilineatus* **B** *T. persimilis* **C** *Thamnodynastes nattereri* **D** *Tomodon dorsatus* **E** *Tropidodryas serra* **F** *Xenodon neuwiedii* **G** *Micrurus corallinus* **H** *Tropidophis paucisquamis*.

anterior part of the body (Martins et al. 2008), or elevate the head while compressing the body (Greene 1979) in a manner similar to Old World elapids (Table 3).

Figure 7. A *Bothrops jararaca* (photo: Rafael Menegucci) **B** *B. jararacussu*.

Elapidae Boie, 1827

Micrurus corallinus (Merrem, 1820)

This is a proteroglyphous species of medium size (only juveniles were captured, with maximum SVL = 251 mm; *N* = 5; adults exceed 900 mm in total length; Roze 1996). One individual was captured in a pitfall trap in the peach palm plantation, another was found inside a house, and a third was caught crossing an unpaved road near the forest edge in the early morning. The other three were active during the day in unpaved roads close to disturbed habitats. It is primarily diurnal, and it forages on the ground or in underground galleries capturing caecilians, amphisbaenians, lizards and other snakes (Roze 1996, Marques and Sazima 1997, Banci et al., 2017). Only juveniles were found at the Etá Farm (< 400 mm), in April, July and August. The species has a seasonal reproductive cycle with mating and vitellogenesis occurring at the beginning of the rainy season (Marques 1996b, Almeida-Santos et al. 2006, Marques et al. 2006). Fecundity ranges from 2–12 eggs (Marques 1996b). When handled, one individual from the Etá Farm raised the curled the tail. This coral snake flattens its body, hides its head, performs erratic movements and elevates its head, while compressing its body, and raises the curled tail (Greene 1979, Marques et al. 2019) (Table 3).

Viperidae Laurenti, 1768

Bothrops jararaca (Wied, 1824)

This is a solenoglyphous species of large size (maximum SVL = 1220 mm; *N* = 23). It was found in all sampled vegetation types (eight individuals in peach palm plantation, four in forests, and one in the abandoned banana plantation), but never in pitfall traps. It was also found in operating banana plantations (*N* = 5). The other five individuals were caught in other disturbed habitats. Most individuals found were coiled up in the undergrowth during the day, in the peach palm plantation; one individual was found around houses and two on an unpaved road, one of them near the forest edge and the other in a pasture area. One adult male was found moving on the ground in the afternoon (15:00 h) in the abandoned banana plantation, one juvenile was found moving over a bromeliad on a fallen trunk at night (see also Marques 1998) and one adult male was found moving on the forest ground at 22:00 h. The available information indicates that it is semi-arboreal and primarily nocturnal (Sazima and Manzani 1995, Alves et al. 2000, Martins et al. 2001, Forlani et al. 2010, this study). In the digestive tracts of three specimens examined we found rodents, one of them belonging to the tribe Akodontini (Table 2). The available information indicates that it feeds mainly on rodents and amphibians, in addition to lizards, birds and centipedes, with a relatively higher consumption of ectothermic prey by juveniles and endothermic prey by adults (Sazima and Manzani 1995, Martins et al. 2002, Hartmann et al. 2009b); there have been reports of necrophagy in this species (Sazima and Strüssmann 1990). Five females from the Etá Farm had 13–35 vitellogenic follicles, throughout the year. One gravid female captured in January contained 10 fully formed embryos (SVL = 191 ± 15.23 mm, weight = 7.48 ± 1.29 g). Juveniles (< 400 mm) were mainly observed in the hotter and rainier months of the year (October to February). The available information indicates that it has a biennial, seasonal reproductive cycle, with vitellogenesis occurring between autumn and winter, ovulation probably in early spring, copulation at the beginning of the dry season and pregnant females from November to March (Janeiro-Cinquini 2004, Almeida-Santos and Salomão 2002, this study). Fecundity varies from 3–36 offspring and gestation may last 152–239 days (Alves et al. 2000, Janeiro-Cinquini 2004, Sazima 1992, Almeida-Santos and Salomão 2002, Costa et al. 2010, this study). It was found throughout the year at the Etá Farm. When handled, individuals from the Etá Farm vibrated the tail (*N* = 6) and struck (*N* = 4). The Information available in the literature indicates that it may also flatten its body and perform cloacal discharge (Marques et al. 2019) (Table 3).

***Bothrops jararacussu* Lacerda, 1884**

This is a solenoglyphous species of large size (maximum SVL = 1150 mm; *N* = 47). It was found in all sampled vegetation types (23 individuals in the peach palm plantation, six in forest and four in banana plantations), coiled up in the undergrowth, often at the base of the peach palms (*N* = 17), in open areas or on the leaf litter in the forest (*N* = 4); only two juveniles were captured in pitfall traps, in the abandoned banana plantation and the peach palm plantation. Nine individuals were found on the unpaved road, three of them at the edge of forest, one of which had just ingested an individual of *Sordellina punctata*, and three near pasture areas. The other five individuals were caught in other disturbed habitats. The available information indicates that it is terrestrial and frequently found close to watercourses; it has mostly nocturnal activity, although juveniles and eventually adults may hunt during the day (Martins et al. 2002, Marques and Araujo 2011, M. Martins, personal observation). Approximately 63% of the specimens (*N* = 12) whose digestive tracts were examined had rodents (Table 2) that, in all cases where it was possible to assess, had been ingested headfirst. One specimen contained the bones of an opossum. The population of the Etá Farm seems to show an ontogenetic change in diet, with juveniles feeding mainly on ectothermic animals, including a snake (*Sordellina punctata*), frogs of the families Hylidae and Leptodactylidae, and a centipede, and adults feeding primarily on small mammals. However, adult individuals may occasionally consume ectothermic prey, as in the case of one adult male containing a rodent and a leptodactylid frog in its digestive tract (Table 1). The available information indicates that it feeds on centipedes, frogs, lizards and mammals, with ontogenetic variation in diet, with juveniles mainly feeding on ectothermic animals (especially frogs) and adults mainly feeding on small mammals (Lema et. al. 1983, Martins et. al. 2002, Hartmann et al. 2009b, this study). At the Etá Farm it was found throughout the year; however, most individuals were found in the hotter and rainier months (October–April). Two females had vitellogenic follicles in June and July and one had secondary follicles in January. Most juveniles were observed in December and February. The available information indicates that the reproductive cycle of this species is seasonal; mating occurs in May and June, and births are concentrated in March, with 13–37 hatchlings (Marques 1998, Almeida-Santos and Salomão 2002). When handled, individuals from the Etá Farm struck (*N* = 2) and vibrated the tail on the ground (*N* = 5). Information available in the literature indicates that it may also flatten its body and perform cloacal discharge (Marques et al. 2019) (Table 3).

Discussion

The snake assemblage of the Etá Farm region has a species composition similar to those of other studied assemblages in the Ribeira River Valley (e.g., Marques 1998, Forlani et al. 2010). The new records for Sete Barras Municipality (*C. fuscus*, *C. laevicollis*, *E. cephalostriata*, *Spilotes pullatus*, and *T. bilineatus*) were already expected to occur in the region, because they are typical Atlantic Forest species and their distributions overlap Sete Barras region (Nogueira et al. 2019). All species that potentially occur in the Etá Farm region are typical forest species (Marques et al., 2019, Nogueira et al. 2019) and most of them are semi-arboreal (Marques and Cavalheiro 1998, Martins et al. 2008, Antunes and Haddad 2009, Hartmann et al. 2009ab, Marques et al. 2019) and though most species found in the field present diurnal activity, when species of potential occurrence are added, most species of the assemblage are nocturnal (Martins et al. 2008, Antunes and Haddad 2009, Hartmann et al. 2009ab, Marques et al. 2019). The main prey of these species are amphibians (*C. bicarinatus*, *C. foveatus*, *E. cyanopleura*, *E. undulata*, *T. persimilis*, *T. nattereri*, and *T. paucisquamis*; Dixon et al. 1993, Antunes and Haddad 2009, Marques et al. 2019), slugs (*D. albifrons*, *D. alternans*, *D. indica* and *D. variegata*; Sazima 1989, Forlani et al. 2010, Marques et al. 2019), mammals and birds (*C. cropanii*, *C. hortulanus*; Marques and Cavalheiro 1998, Marques et al. 2019), elongate vertebrates (*C. plumbea*; Gaiarsa et al. 2013), and amphibians and lizards in *I. cenchoa*, *S. pulcher*, and *T. serra* (Marques et al. 2019). As for the conservation status of snakes from the Etá Farm region, *Corallus cropanii* is categorised as Endangered (EN) in the red list of the International Union for the Conservation of Nature (IUCN 2019), in the Brazilian red list (ICMBio 2018), as well as in the São Paulo State red list

(São Paulo 2019). It is known from only five localities and the most recent published record is from Sete Barras (Machado-Filho et al 2011).

Of the species recorded in the study area, most used both forested (or were at least observed in forest edges) and open areas, except for *C. exoletus*, *D. neuwiedi*, *S. pullatus*, and *T. dorsatus*, which were observed only in disturbed areas (banana and peach palm plantations). The peach palm plantations, surrounded by forested areas may be functioning as routes from one edge to the other of the forested areas, and as foraging sites (as they have large quantities of frogs and molluscs; see Fiorillo et al. 2018). However, the edges of a given habitat tend to be hostile to organisms adapted to living in its interior and may contain both competitors and predators (Andrén and Angelstam 1988, Chalfoun et al. 2002). Even so, some snakes from the region of the Etá Farm seem to benefit from using these areas.

The colubrids of the assemblage, as well as the xenodontines, are mostly anuran specialists (Marques et al. 1998, Marques et al. 2019, this study), except for *S. pullatus*, which differed from other colubrids by showing a diet based mainly on small mammals and nestling birds (Marques 1998, Marques et al. 2019, this study). The anuran prey and substrate use differ among the diurnal frog-eating species. *Chironius* spp. prey on leptodactylid and hylid frogs at various substrate heights, *X. neuwiedii* search mainly by *Rhinella* spp. in the forest ground and in disturbed areas and *E. cephalostriata* and *T. bilineatus* consume mainly small frogs commonly found amid the leaf litter, such as *Adenomera* cf. *marmorata*, *Haddadus binotatus*, *Ischnochnema* sp., and *Physalaemus spiniger* (Fiorillo et al. 2018), and occasionally their eggs (e.g., *E. cephalostriata*, see Moura-Leite et al. 2003).

The nocturnal and terrestrial species, *B. jararaca*, *B. jararacussu*, and *O. clathratus* show similar diet and were all found in both open, disturbed areas and in forested areas. Although marsupials (e.g., *Monodelphis americana*) were restricted to forested areas, rodents were abundant in both habitat types. However, juveniles of these species feed on ectothermic prey (*O. clathratus* feeds on lizards and *Bothrops* spp. feeds mainly on frogs). It is known that *O. clathratus* is occasionally found in open and disturbed areas (Di-Bernardo et al. 2007, Hartmann and Giasson 2008, Hartmann 2009b). Being an almost strictly terrestrial species (Hartmann and Giasson 2008, Hartmann et al. 2009a, Barbo et al. 2011), probably it is not as restricted to forested habitats as other species that use arboreal substrates more often (e.g., *Chironius* spp.). However, it is important to consider that even the disturbed habitats in which the species was found, were surrounded by forest. In addition, the disturbed habitats sampled (banana and peach palm plantations) presented a considerable abundance of frogs (see Fiorillo et al. 2018), which in turn would favour the foraging of *Bothrops* species. The malacophagous species, *D. neuwiedii* and *T. dorsatus*, show terrestrial behaviour, but distinct daily activities (nocturnal for the former, diurnal for the latter), and both are found in open areas where the molluscs are abundant (personal observation). Two of the slug species consumed by *D. neuwiedii* are invasive species, the European *Limax* cf. *flavus* and the Chinese *Meghimatium pictum*. Thus, these malacophagous snakes can potentially control the populations of invasive molluscs.

Although annelids have been previously reported for the diet of *S. punctata* (Marques 1998, Marques et al. 2019), we here provided the first report of consumption of leeches by this species. This prey, earthworms (including aquatic giant earthworm) and one caecilian (previously reported by Proctor, 1923) confirm that this snake forages in aquatic habitats.

Most individuals were found during the hot and rainy season from September to March, when most species show reproductive activity, as may be seen by the presence of vitellogenic follicles for some species and mating (e.g., *S. pullatus*). This seasonal activity peak has been reported for other assemblages of Neotropical snakes (Strüssmann and Sazima 1993, Martins and Oliveira 1998, Marques 1998, Sawaya et al. 2008b, Pontes et al. 2009) and seems to reflect the effect of environmental variables favouring snake metabolism for the development of eggs or offspring. The exceptions were *E. aesculapii*, which had vitellogenic follicles in July; *E. miliaris*, which also presented secondary vitellogenic follicles from April to August, although smaller in the hottest period of the year; and the vipers *B. jararaca* and *B. jararacussu*, which showed vitellogenic follicles in both the hot and rainy season and during the month of June. Females of *E. aesculapii* and *X. neuwiedii* show vitellogenic follicles in every month of the year (Jordão 1996, Marques 1996a, Pizzatto et al. 2008). These two species belong to the tribe Xenodontini and continuous reproductive cycles may be conservative in this lineage of snakes (Pizzatto et al. 2008). Additionally, the type of resource used by these species may enable a continuous reproductive cycle (Vitt and Vangilder 1983, Seigel and Ford 1987), as these species feed on prey that are abundant throughout the year (Seigel and Ford 1987, Roberto et al. 2011).

The reproductive cycle of another member of the tribe Xenodontini, *E. miliaris*, varies along its distribution and, although vitellogenic follicles were observed from April to August (two individuals), the population of the Etá Farm region is characteristic of the southern coastal region of the Atlantic Forest, where the reproductive cycle of this species may be seasonal (Pizzatto and Marques 2006). This reproductive peak during the hotter and rainier months, as well as with other species in the assemblage (members of the genus *Chironius*), may be related to the temporal distribution of frogs, because, as in other species of the genus (e.g., *E. poecilogyrus*, see Alencar and Nascimento 2014), female *E. miliaris* apparently do not stop feeding during vitellogenesis until the deposition of the eggs (two females containing secondary follicles and one female with eggs in the oviducts had stomach contents), a characteristic that may be related to the possibility of foraging during the reproductive period (Winne et al. 2006, Dyke et al. 2012). Alternatively, Oliveira and Martins (2001) suggested that snakes, as well as frogs, may simply be responding to the same environmental variables (or set of variables) and, thus, their activity peaks coincide in time.

The results described herein for the reproduction of *B. jararaca* and *B. jararacussu* corroborate the results of other studies that describe the reproductive phenology for the genus *Bothrops* (Almeida-Santos and Salomão 2002, Janeiro-Cequini 2004). These studies suggest that copulation occurs from April to September, when the animals are in vitellogenesis, there is a reduction of ovarian mass from October to March, probably due to ovulation and advanced pregnancy occurs during the rainy season (see the account of *B. jararaca* in Results). These patterns occur due to the storage of sperm in females and late fertilisation, which allows mating to occur in one season and follicular development, fertilisation and parturition to occur in another. Moreover, it provides females with the possibility of repeated fertilisation in a single mating event (Birkhead and Moller 1993, Marques 1996b).

Most defensive tactics observed at the Etá Farm were apparently aimed at visually oriented predators such as birds (especially birds of prey), important predators of Neotropical snakes, and some mammals (Sazima 1992, Martins and Oliveira 1998, Martins 1996, Martins et al. 2008). However, in the case of mammals, these tend to show nocturnal activity and, thus, to use mainly their sense of smell and hearing as the main ways to locate their prey (Martins 1996). Thus, a defensive tactic such as cloacal discharge (employed by 70% of the species in the region, considering field observations and literature data; see Table 3) could be more effective. Alternatively, Martins (1996) suggest that defensive tactics seem to correlate with phylogeny, therefore, cloacal discharge (a defensive behaviour with apparently low energy costs) may have been the most frequent behaviour observed simply because it is a common, well established, widespread behaviour among snakes in their evolutionary history.

Another defence shown by many species was cryptic colouration (82%), which is common for diurnal species (58% of the assemblage; Martins & Oliveira, 1998). In contrast, only one species showed aposematic colouration (*M. corallinus*) and two (*E. aesculapii* and *O. clathratus*) are supposed mimics of the coral snakes (Greene and McDiarmid 2005; Martins et al., 2008). Many of the trends in defensive tactics observed in this study are similar to those found by previous works in the Central Amazon (Martins 1996, Martins and Oliveira 1998, Martins et al. 2008), including: (1) inaccessibility (e.g., see the account of *C. laevicollis*); (2) many species employ tactics like fleeing, compressing their bodies, and biting; (3) all diurnal species are cryptic, except for the aposematic species, *M. corallinus*, and the supposed coral snake mimic, *E. aesculapii* (additionally, although not observed in this study, there are reports in the literature of the same defensive behaviours of *M. corallinus* performed by *E. aesculapii*); and (4) head triangulation was commonly used by supposed mimics of pitvipers (e.g., *D. neuwiedii*, *X. neuwiedii*; Greene and McDiarmid 2005), but also by *E. miliaris*.

A poorly documented visual defensive behaviour was reported for *E. miliaris* at Fazenda Etá (Menezes et al. 2015; this study). Two individuals (one juvenile and one adult) were observed simultaneously raising and compressing the anterior part of their body, a behaviour commonly performed by Old World elapids and previously reported for other Neotropical snakes, for example, species of the genera *Thamnodynastes*, *Hydrodynastes*, and *Xenodon* (Franco et al. 2003, Young and Kardong 2010, Kahn 2011). It is likely that this behaviour has the same goal of intimidating the predator as other frontal displays previously described, such as raising the head and inflating the glottis, which alter the predator's perception of the size of the individual that performs them (Greene 1988, 1997, Young and Kardong 2010).

Conclusions

The region of the Etá Farm harbours a rich snake fauna that is similar in composition to those of other snake assemblages in the Ribeira River Valley and includes one threatened species. This study contributed to the knowledge of the snake fauna of this region also by providing five new records for the Sete Barras Municipality. The detailed natural history information provided herein may be used in the assessment of the conservation status of these snakes and in the definition of action plans aiming to conserve this rich and biologically diverse fauna.

Keys to families and species of snakes from Sete Barras region, southeastern Brazil

1 Loreal pit present; solenoglyphous dentition; keeled dorsal scales.. **Viperidae**

– Labial pits present; aglyphous dentition; smooth dorsal scales; large size .... **Boidae**

2 Labial pits absent; small size; stout body; usually 21 or 23, rarely 25 midbody dorsal scale rows; 164–183 ventral plates; 15–19 maxillary teeth .... **Tropidophiidae (*Tropidophis paucisquamis*)**

– Proteglyphous dentition; small black eyes; loreal shield absent; coral colour pattern, with single black rings between two narrow white rings .... **Elapidae (*Micrurus corallinus*)**

3 Aglyphous or opistoglyphous dentition; top of head covered by large, distinct and symmetrical scales .... **Colubridae and Dipsadidae**

Viperidae

1 Dorsal spots in inverted "V" shape, bordered by lighter colours; belly lighter with irregular spots; 20–37 dorsal scale rows; 170–216 ventral plates; 44–71 subcaudal plates; 6–10 supralabial scales .... ***Bothrops jararaca***

– Trapezoid dorsal spots, bordered by lighter colours; light-yellow belly; 23–29 dorsal scale rows; 166–186 ventral scales; eight supralabial scales .... ***Bothrops jararacussu***

Boidae

1 Olive-beige dorsum, with dark-brown rhomboidal spots from the neck to half of the tail; yellow ventral scales; 29–32 dorsal scale rows at midbody .... ***Corallus cropanii***

– Extremely variable dorsal patterns, from grey to brown, yellow to orange and red; cream to light grey belly; 47–63 dorsal scale rows at midbody................................ ***Corallus hortulanus***

Colubridae and Dipsadidae

1 Even number of dorsal scale rows..**2**

– Odd number of dorsal scale rows..**7**

2 More than 14 dorsal scale rows at midbody; apical pits present; dorsal background black; yellow belly colour invades the dorsolateral region..***Spilotes pullatus***

– 10 to 12 dorsal scale rows at midbody; single cloacal plate..**3**

3 10 dorsal scale rows at midbody; dorsal colour brown with shades of olive; keeled paravertebral scales; maxillary teeth 39–51 ....***Chironius fuscus***

– 10 or 12 dorsal scale rows at midbody; apical pit single and only on the neck scales..**4**

4 Adults with head, supralabial scales and anterior region of the body black; yellowish belly; juveniles are born completely green; 156–165 ventral scales; maxillary teeth 32–39..***Chironius laevicollis***

– Divided cloacal shield..**5**

5 Eight posterior dorsal scale rows; anterior third of body olive green, turning to brownish in the other two thirds; light belly; 123–162 ventral scales; 111–160 subcaudal scales; 24–34 maxillary teeth ....***Chironius exoletus***

– Ten posterior dorsal scale rows...**6**

6 Light green dorsum; belly light with shades of yellow; 163–174 ventral scales; 156–169 subcaudal scales; 32–37 maxillary teeth ....***Chironius foveatus***

– Dorsal colour olive green with a lighter vertebral stripe; yellow belly; 149–169 ventral scales; 121–157 subcaudal scales; 28–40 maxillary teeth ....***Chironius bicarinatus***

7 17 or less dorsal scale rows at midbody **8**

– 19 or more dorsal scale rows at midbody..**18**

8 15 dorsal scale rows at midbody..**9**

– 17 dorsal scale rows at midbody..**13**

9 Big black eyes; coral colour pattern; opistoglyphous dentition ....***Erythrolamprus aesculapii***

– Medium-sized eyes; colour pattern not coral-like **10**

10 Top of head with several spots; aglyphous dentition; vertebral scale row distinctly larger than the other dorsal scales; belly with thin spots, forming irregular and rather interrupted longitudinal lines, 161–184 ventral scales; 56–83 subcaudal scales ....***Dipsas neuwiedi***

– Laterally compressed body; head extremely distinct from the body; large eyes..**11**

11 A pair of parallel spots on top of head; irregular dorsal spot pattern; slightly enlarged vertebral scale row; 11–15 maxillary teeth............***Dipsas albifrons***

– A pair of white-bordered ocelli on top of head; beige dorsum, with dark round, well-defined blotches, thinly bordered by white......***Dipsas alternans***

12 Top of head blotched to mostly immaculate, but never with distinctive inverted U or V shaped blotches with light centres................***Dipsas variegata***

– Head with or without large parietal spots, otherwise mostly immaculate; 16–26 dorsal blotches ....***Dipsas indica***

13 Dark oral lining; opistoglyphous dentition; large fangs; 134–143 ventral scales; 31–28 subcaudal scales; eight or less maxillary teeth.......... ***Tomodon dorsatus***

– Light oral lining..**14**

14 Body uniformly black, with a series of light lateroventral spots; light spots on the supralabial scales; medium-sized eyes; subelliptical pupils; 135–174 ventral scales; 36–57 subcaudal scales ....***Sordellina punctata***

– Each dorsal scale with a lighter centre, with dark borders; medium-sized eyes; 142–171 ventral scales; 39–64 subcaudal scales ....***Erythrolamprus miliaris orinus***

15 Well-defined line along the *canthus rostralis* from the snout to the post-ocular region; top of head, dark; yellow belly; 8–23 maxillary teeth......................... .... ***Taeniophallus bilineatus***

– Supralabial scales and chin region usually stained by black; no postocular stripe; 51–82 subcaudal scales; less than 140 ventral scales .... ***Taeniophallus persimilis***

16 Continuous lateral postocular stripe; white lateral line at the fourth dorsal row; light brown dorsum; yellow belly, with a pair of black dots on each ventral scale; 142–160 ventral scales; 80–100 subcaudal scales ....***Echinanthera cephalostriata***

– A pair of light spots on the occipital region; dark middorsal band on the neck, usually with irregular borders..................................***Echinanthera undulata***

17 Supracephalic dark colouration extends to the middle of the dorsum, creating a dark dorsal band that contrasts with the paravertebral ground colour at least on the neck; anterior part of the dark pleural band usually regularly edged... .... ***Echinanthera cyanopleura***

– Body strongly laterally compressed and long; head very distinct from the body; large eyes; elliptical pupil; vertebral dorsal scale row different from the paravertebral rows; dorsum brown with dark diamond-shaped blotches........ .... ***Imantodes cenchoa***

18 Single internasal shield, dark-brown or black dorsum; belly cream with two (sometimes three) medial rows of black semilunar marks; 130–148 ventral scales; 48–73 subcaudal scales .... ***Helicops carinicaudus***

– Paired internasal scales **19**

19 Head uniformly black; long snout; numerous bands along the body, uniformly distributed and not continuous on the belly; 183–221 ventral scales; 46–88 subcaudal scales .... ***Oxyrhopus clathratus***

– Thin and laterally compressed body; head very distinct from the body; large red eyes; long, thin tail; anterior maxillary teeth longer than the rear ones;

some vertebral scales are red or orange; the red spots on the dorsum occupy 4–7 scale rows .... ***Siphlophis pulcher***

20 Black or dark-brown colouration; juveniles have a white stripe on the head and a dark wine-red nuchal stripe; 198–243 ventral scales; 70–97 subcaudal scales; vertical pupils; smooth dorsal scales .... ***Clelia plumbea***

– Non-globular eye; cylindrical body; thick neck; intensely pigmented gular region; 142–167 ventral scales. .... ***Thamnodynastes nattereri***

21 Dorsoventral compression of the body; oblique dorsal scale rows; aglyphous dentition; 6–14 maxillary teeth, with additional pair of large laminate rear fangs .... ***Xenodon neuwiedii***

– Light brown dorsum, with square-shaped blotches; head, distinct from the body; laterally compressed body; slightly keeled dorsal scales .... ***Tropidodryas serra***

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References

Achaval F, Olmos A (1997) Anfibios y reptiles del Uruguay. Facultad de Ciencias, Montevideo, 128 pp.

Albolea ABP (1998) Padrões de atividade em serpentes não peçonhentas de interesse médico: *Helicops modestus* (Colubridae: Xenodontinae) e *Liophis miliaris* (Colubridae: Xenodontinae) e sua relação com a epidemiologia. Master's Dissertation, Guarulhos, Brazil: Universidade de Guarulhos.

Alencar LRV (2010) Ecomorfologia em serpentes neotropicais: um estudo de caso com a tribo Pseudoboini. Master's Dissertation, São Paulo, Brazil: Universidade de São Paulo.

Alencar LRV, Nascimento LB (2014) Natural history data of a common snake suggest interpopulational variation and conservatism in life history traits: the case of *Erythrolamprus poecilogyrus*. The Herpetological Journal 24: 79–85. https://www.thebhs.org/publications/the-herpetological-journal/volume-24-number-2-april-2014/738-02-natural-history-data-of-a-common-snake-suggest-interpopulational-variation-and-conservatism-in-life-history-traits-the-case-of-i-erythrolamprus-poecilogyrus-i?

Almeida-Santos SM, Salomão MG (2002) Reproduction in Neotropical Pitvipers with emphasis on species of genus *Bothrops*. In: Schuett GW, Höggren M, Douglas ME, Greene HW (Eds) Biology of the Vipers. Eagle Mountain Publishing, LC, 445–462.

Almeida-Santos SM, Pizzatto L, Marques OAV (2006) Intra-sex synchrony and intersex coordination in the reproductive timing of the coral snake *Micrurus corallinus* (Elapidae). The

Herpetological Journal 16: 371–376. http://www.ingentaconnect.com/contentone/bhs/thj/2006/00000016/00000004/art00005

Altmann J (1974) Observational Study of Behavior: Sampling Methods. Behavior 49: 227–267. https://doi.org/10.1163/156853974X00534

Alves, MLM, Araujo ML, Witt AA (2000) Aspectos da Biologia Reprodutiva de *Bothrops jararaca* em Cativeiro (Serpentes: Viperidae). Iheringia Série Zool. 89: 187–192. https://doi.org/10.1590/S0073-47212000000200009

Amaral A (1930) Notes on *Spilotes pullatus*. Bull. Antiven Institute of America 3: 96–99.

Andren H, Angelstam P (1988) Elevated Predation Rates as an Edge Effect in Habitat Islands: Experimental Evidence. Ecology 69: 544–547. https://doi.org/10.2307/1940455

Antunes AP, Haddad CFB (2009) *Tropidophis paucisquamis*. Diet and Caudal luring. Herpetological Review 40: 104.

Araújo CO, Condez TH, Bovo RP, Centeno FC, Luiz AM (2010) Amphibians and reptiles of the Parque Estadual Turístico do Alto Ribeira (PETAR), SP: an Atlantic Forest remnant of Southeastern Brazil. Biota Neotropica 10: 257–274. https://doi.org/10.1590/S1676-06032010000400031

Banci, KRS, Viera NFT, Freitas AC, Marques OAV (2017) Feeding on elongate prey: additional data for the coral snake Micrurus corallinus (Merrem, 1820) (Elapidae) and comments on aposematism. Herptolgy Notes 10: 335–338. https://www.biotaxa.org/hn/article/view/28286/28161

Barbo FE (2008) Os Répteis no Município de São Paulo: aspectos históricos, diversidade e conservação. In: Malagoli LR, Bajestero FB, Whately M (Eds) Além do Concreto: contribuições para a proteção da biodiversidade paulistana. Editora Instituto Socioambiental, São Paulo, 234–267.

Barbo FE, Marques OAV, Sawaya RJ (2011) Diversity, natural history, and distribution of snakes in the municipality of São Paulo. South American Journal of Herpetology 6: 135–160. https://doi.org/10.2994/057.006.0301

Beebe W (1946) Field notes on the snakes of Kartabo, British Guiana, and Caripito, Venezuela. Zoologica 31: 11–52. https://www.biodiversitylibrary.org/page/50979101

Bernarde PS, Abe AS (2006) A Snake Comunity at Espigão do Oeste, Rondônia, Southwestern Amazon, Brazil. South American Journal of Herpetology 1: 102–113. https://doi.org/10.2994/1808-9798(2006)1[102:ASCAED]2.0.CO;2

Birkhead TK, Moller AP (1993) Sexual selection and the temporal separation of the reproductive events: sperm storage data from reptiles, birds and mammals. Biological Journal of the Linnean Society 50: 295–311. https://doi.org/10.1111/j.1095-8312.1993.tb00933.x

Bizerra AF (1998) História natural de *Tomodon dorsatus* (Serpentes, Colubridae). Master's Dissertation, São Paulo, Brazil: Universidade de São Paulo.

Bizerra AF, Marques OAV, Sazima I (2005) Reproduction and feeding of the colubrid snake *Tomodon dorsatus* from southeastern Brazil. Amphibia-Reptlia 26: 33–38. https://doi.org/10.1163/1568538053693350

Brooks DR, McLennan DA (2002) The Nature of Diversity: An Evolutionary Voyage of Discovery, University of Chicago Press, Chicago, 676 pp. https://doi.org/10.7208/chicago/9780226922478.001.0001

Caughley G (1994) Directions in conservation biology. Journal of Animal Ecology 63: 215–244. https://doi.org/10.2307/5542

Carreira VS (2002) Alimentación de los ofidios de Uruguay. Asociación Herpetológica Española, Monografías de Herpetología, 127 pp.

Cechin SZ (1999) História natural de uma comunidade de serpentes na região da depressão central (Santa Maria Rio Grande do Sul, Brasil. Ph.D. Thesis, Porto Alegre, Brazil: Pontífica Universidade Católica do Rio Grande do Sul.

Cechin SZ, Martins M (2000) Eficiência de armadilhas de queda (Pitfall traps) em amostragens de anfíbios e répteis no Brasil. Revista Brasileira de Zoologia 17: 729–749. https://doi.org/10.1590/S0101-81752000000300017

Chalfoun AD, Ratnaswamy MJ, Thompson FR (2002) Songbird nest predators in forest-pasture edge and forest interior in a fragment landscape. Ecological Applications 12: 858–867 https://doi.org/10.1890/1051-0761(2002)012[0858:SNPIFP]2.0.CO;2.

Condez TH, Sawaya RJ, Dixo M (2009) Herpetofauna dos remanescentes de Mata Atlântica da região de Tapiraí e Piedade, SP, sudeste do Brasil. Biota Neotropica 9: 157–185. https://doi.org/10.1590/S1676-06032009000100018

Costa ACOR, Hauzman E, Scartozzoni RR (2005) *Chironius laevicollis* (Pale-necked whipsnake): Reproduction. Herpetological Bulletin 92: 26–27.

Costa HC, Bérnils RS (2018) Répteis do Brasil e suas Unidades Federativas: Lista de espécies. Herpetologia Brasileira 7: 11–57. http://sbherpetologia.org.br/wp-content/uploads/2018/04/hb-2018-01-p.pdf

Costa, HC, Martins LB, Carvalho TR (2012) *Xenodon neuwiedii* (Serpentes: Xenodontinae): Dieta. Herpetologia Brasileira 1: 38–41. http://sbherpetologia.org.br/wp-content/uploads/2017/04/HB-2012.01-P.pdf

Costa HC, Pantoja DL, Pontes JL, Feio RN (2010) Snakes of the Municipality of Viçosa, Atlantic Forest of Southeastern Brazil. Biota Neotropica 10: 353–376. https://doi.org/10.1590/S1676-06032010000300033

Dayton PK (2003) The importance of the natural sciences to conservation. The American Naturalist 162: 1–13. https://doi.org/10.1086/376572

Di-Bernardo M (1999) História natural de uma Comunidade de Serpentes da Borda Oriental do Planalto das Araucárias, Rio Grande do Sul, Brasil. Ph.D. Thesis. Universidade Estadual de Paulista, São Paulo, Brazil.

Di-Bernardo M, Borges-Martins M, Oliveira RB, Pontes GMF (2007) Taxocenoses de serpentes de regiões temperadas do Brasil. In: Nascimento LB, Oliveira ME (Eds) Herpetologica no Brasil II. Belo Horizonte, Sociedade Brasileira de Herpetologia, 222–263.

Di-Bernardo M, Lema T (1990) O gênero *Rhadinaea* Cope, 1863, no Brasil meridional. IV. *Rhadinaea bilineata* (Fischer, 1885) (Serpentes, Colubridae). Acta Biologica Leopoldensia 12: 359–392.

Dixon JR, Soini P (1986) The Reptiles of the upper amazona Basin, Iquitos region, Perú. Milwaukee Public Museum, Milwaukee, 154 pp.

Dixon JR, Wiest Jr JA, Cei JM (1993) Revision of the Neotropical snakes genus *Chironius* Fitizinger (Serpentes, Colubridae). Monografie Museo Regionale di Scienze Naturali di Torino 13: 1–279.

Dyke JUV, Beaupre SJ, Kreider DL (2012) Snakes allocate amino acids acquired during vittelogenesis to offspring: are capital and income breeding consequences of variable foraging success? Biological Journal of Linnean Society 106: 390–404. https://doi.org/10.1111/j.1095-8312.2012.01880.x

Forlani MC, Bernardo PH, Haddad CFB, Zaher H (2010) Herpetofauna do Parque Estadual Carlos Botelho, São Paulo, Brasil. Biota Neotropica 10: 265–309. https://doi.org/10.1590/S1676-06032010000300028

França GRF, Araújo FBA (2006) The Conservation Status of Snakes in Central Brazil. South American Journal of Herpetology 1: 25–36. https://doi.org/10.2994/1808-9798(2006)1[25:TCSOSI]2.0.CO;2

Franco FL, Cintra LAC, Lema TA (2006) A New Species of *Calamodontophis* Amaral, 1963 (Serpentes, Colubridae, Xenodontinae) from Southern Brazil. South American Journal of Herpetology 1: 218–226. https://doi.org/10.2994/1808-9798(2006)1[218:ANSOCA]2.0.CO;2

Franco FL, Ferreira TG, Marques OAV, Sazima I (2003) A new species of hood-displaying *Thamnodynastes* (Serpentes: Colubridae) from the Atlantic forest in southeast Brazil. Zootaxa 334: 1–7. https://doi.org/10.11646/zootaxa.334.1.1

Freitas MA (1999) "Serpentes da Bahia e do Brasil". Guia ilustrado com descrição, biologia de cada espécie e a distribuição das mesmas no estado da Bahia. Feira de Santana/BA: Legal Editora Gráfica LTDA, Santana, 80 pp.

Gaiarsa MP, Alencar LRV, Martins M (2013) Natural History of Pseudoboine Snakes. Papéis Avulsos de Zoologia 53: 261–283. https://doi.org/10.1590/S0031-10492013001900001

Governo do Estado de São Paulo (2018) Diário Oficial. Decreto N° 63.853, 128: 1–10.

Greene HW (1979) Behavioral convergence in the defensive displays of snakes. Experientia 35: 747–748. https://doi.org/10.1007/BF01968221

Greene HW (1994) Systematics and natural history foundations for understanding and conserving biodiversity. American Zoologist 34: 48–56. https://doi.org/10.1093/icb/34.1.48

Greene HW (1988) Antipredator mechanisms of reptiles. In: Gans C, Huey RB (Eds) Biology of the Reptilia. Alan R. Liss, New York, 1–152.

Greene HW (1997) Snakes: The Evolution of Mystery in Nature. University of California Press, Berkeley, CA, 351 pp.

Greene HW (2005) Organisms in nature as a central focus for biology. Trends in Ecology & Evolution 20: 23–27. https://doi.org/10.1016/j.tree.2004.11.005

Greene HW, McDiarmid RW (2005) Wallace and Savage: heroes, theories, and venomous snake mimicry. In: Donnelly MA et al. (Eds) Ecology and Evolution in the Tropics: A Herpetological Perspective. University of Chicago Press, Chicago, 190–208.

Guedes TB, Nogueira C, Marques OAV (2014) Diversity, natural history, and geographic distribution of snakes in the Caatinga, Northeastern Brazil. Zootaxa 3863: 001–093. https://doi.org/10.11646/zootaxa.3863.1.1

Hartmann PA, Giasson LO (2008) Répteis. In: Cherem JJ, Kammers M (Eds) A fauna das áreas de influencia da usina hidreletrica Quebra Queixo. Editora Habilis, Rio Grande do Sul, Erechim, 111–130.

Hartmann PA, Hartmann MT, Martins M (2009a) Ecologia e história natural de uma taxocenose de serpentes no Núcleo Santa Virgínia do Parque Estadual da Serra do Mar, no sudeste do Brasil. Biota Neotropica 9: 173–184. https://doi.org/10.1590/S1676-06032009000300018

Hartmann PA, Hartmann MT, Martins M (2009b) Ecology of a snake assemblage in the Atlantic Forest of southeastern Brazil. Papéis Avulsos de Zoologia 49: 343–360. https://doi.org/10.1590/S0031-10492009002700001

Hartmann TA, Hartmann MT, Martins M (2011) Snake Road Mortality in a Protected Area in the Atlantic Forest of Southeastern Brazil. South American Journal of Herpetology 6: 35–42. https://doi.org/10.2994/057.006.0105

Hauzman E, Costa ACOR (2005) *Spilotes Pullatus* (Tiger Ratsnake). Reproduction. Herpetological Review 35: 328.

Hoge AR (1953) A New species and genus of Boinae from Brazil, *Xenoboa cropanii*, Gen. Nov., Sp. Nov. Memórias do Instituto Butantan 25: 27–34. https://bibliotecadigital.butantan.gov.br/edicao/memorias-do-instituto-butantan-vol-25-n-1-1953/34

Instituto Chico Mendes de Conservação da Biodiversidade (2018) Livro Vermelho da Fauna Brasileira Ameaçada de Extinção. ICMBio, Brasília, Brasil, 4162 pp.

Janeiro-Cinquini TRF (2004) Variação anual do sistema reprodutor de fêmeas de *Bothrops jararaca* (Serpentes, Viperidae). Iheringia, Série Zoologia 94: 325–328. https://doi.org/10.1590/S0073-47212004000300017

Joly CA, Leitão-Filho HF, Silva SM (1992) O patrimônio florístico. In: Câmara IB (Ed.) Mata Atlântica Index, Rio de Janeiro, 96–128.

Jordão RS (1996) Estudo comparativo da alimentação e da reprodução de Waglerophis merremi e *Xenodon neuwiedii* (Serpentes: Colubridae). PHd Thesis. Universidade de São Paulo, São Paulo, Brazil.

Kahn TR (2011) Cobra-like hooding and mouth-gapping in an atypically monocle patterned *Xenodon severus* (Linnaeus, 1758): a case of convergent evolutionary behavior? Herpetotropicos 6: 25–26. http://erevistas.saber.ula.ve/index.php/herpetotropicos/article/view/4028

Lema T, Araújo ML, Azevedo ACP (1983) Contribuição para o conhecimento da alimenteção e do modo alimentar de serpentes do Brasil. Comununicações do Museu de Ciências e Tecnologia da PUC-RS, Porto Alegre 26: 41–121.

Machado-Filho PR, Duarte MR, Carmo LF, Franco FL (2011) New record of *Corallus cropanii* (Boidae, Boinae): a rare snake from the Vale do Ribeira, State of São Paulo, Brazil. Salamandra 47: 112–115. http://www.salamandra-journal.com/index.php/home/contents/2011-vol-47/245-machado-filho-p-r-m-r-duarte-l-f-do-carmo-f-l-franco/file

Mantovani W (1993) Estrutura e dinâmica da floresta atlântica na Juréia, Iguape-SP. Master's Dissertation.Universidade de São Paulo, São Paulo, Brazil.

Marques OAV (1996a) Biologia Reprodutiva da Cobra-coral *Erythrolamprus aesculapii* Linnaeus (Colubridae), no sudeste do Brasil. Revista Brasileira de Zoologia 13: 747–753. https://doi.org/10.1590/S0101-81751996000300022

Marques OAV (1996b) Reproduction, seasonal activity and growth of the *Micrurus corallinus* (Serpentes, Elapidae). Amphibia Reptilia 17: 277–285. https://doi.org/10.1163/156853896X00441

Marques OAV (1996c) *Sordellina punctata*. Diet. Herpetological Review 27: 147–147.

Marques OAV (1998) Composição faunística, história natural e ecologia de serpentes da Mata Atlântica, na região da estação ecológica Juréia-Itatins, São Paulo, SP. Phd Thesis, São Paulo, Brazil: Universidade de São Paulo.

Marques OAV (2001) *Sordellina punctata*. Reproduction. Herpetological Review 32: 51–52.

Marques OAV (2010) *Corallus cropanii*. IUCN 2011. IUCN Red List of Threatened Species. Version 2011.2 www.iucnredlist.org

Marques OAV, Almeida-Santos SM, Rodrigues MG (2006) Activity Patterns in Coral Snakes, Genus *Micrurus* (Elapidae), in South and Southeastern Brazil. South American Journal of Herpetology 1: 114–120. https://doi.org/10.2994/1808-9798(2006)1[114:APICSG]2.0.CO;2

Marques OAV, Araujo CO (2011) Do pitvipers prey on mammals during daylight? Herpetology Notes 4: 453–454.

Marques OAV, Cavalheiro J (1998) *Corallus cropanii* (NCN). Habitat and Diet. Herpetological Review 29: 170.

Marques OAV, Eterovic A, Sazima I (2019) Serpentes da Mata Atlântica: Guia ilustrado para as florestas costeiras do Brasil. Ponto A Editora, Cotia, 320 pp.

Marques OAV, Muniz-Da-Silva DF, Barbo FE, Cardoso SRT, Maia DC, Almeida-Santos SM (2014) Ecology of the Colubrid Snake *Spilotes pullatus* from the Atlantic Forest of Southeastern Brazil. Herpetologica 70: 407–416. https://doi.org/10.1655/HERPETOLOGICA-D-14-00012

Marques OAV, Pereira DN, Barbo FE, Germano VJ, Sawaya RJ (2009) Os répteis do município de São Paulo: diversidade e ecologia da fauna pretérita e atual. Biota Neotropica 9: 139–150. https://doi.org/10.1590/S1676-06032009000200014

Marques OAV, Puorto G (1991) Padrões cromáticos, distribuição e possível mimetismo em *Erythrolamprus aesculapii* (Serpentes, Colubridae). Memórias do Instituto Butantan 53: 127–134. https://bibliotecadigital.butantan.gov.br/edicao/memorias-do-instituto-butantan-volume-53-numero-1-1991/15

Marques OAV, Sazima I (1997) Diet and feeding behavior of the Coral Snake, *Micrurus corallinus*, from the Atlantic forest of Brazil. Herpetological Natural History 5: 88–93.

Marques OAV, Sazima I (2003) Ontogenetic color changes may strengthen suggestion about systematic affinities between two species of *Chironius*. Phyllomedusa 2: 65–67. https://doi.org/10.11606/issn.2316-9079.v2i1p65-67

Marques OAV, Sazima I (2004) História natural dos répteis da estação ecológica Juréia-Itatins. In: Marques OAV, Duleba W (Eds) Estação Ecológica Juréia-Itatins: Ambiente Físico, Flora e Fauna. Holos, Ribeirão Preto, 257–277.

Martins M (1996) Defensive tactics in lizards and snakes: the potential contribution of the Neotropical fauna. In: Del Claro K (Ed.) Anais do XIV Encontro Anual de Etologia. Sociedade Brasileira de Etologia, Universidade Federal de Uberlândia, 185–199.

Martins M, Araújo MS, Sawaya RJ, Nunes R (2001) Diversity and evolution of macrohabitat use, body size and morphology in a monophyletic group of Neotropical pitvipers (*Bothrops*). Journal of Zoology 254: 529–538. https://doi.org/10.1017/S0952836901001030

Martins M, Marques OAV, Sazima I (2002) Ecological and Phylogenetic Correlates of Feeding Habits in neotropical Pitvipers of Genus *Bothrops*. In: Schuett GW, Hoggren M, Douglas ME (Eds) Biology of the Vipers. Eagle Mountain Publishing, Utah, 1–22.

Martins M, Marques OAV, Sazima I (2008) How to be Arborial and Diurnal and Still Stay Alive: Microhabitat Use, Time of Activity, and Defense in Neotropical Forest Snakes. South American Journal of Herpetology 3: 58–67. https://doi.org/10.2994/1808-9798(2008)3[58:HTBAAD]2.0.CO;2

Martins M, Oliveira ME (1998) Natural history of snakes in forests of the Manaus region Central Amazonia Brazil. Herpetological Natural History 6: 78–150.

Martins M, Nogueira CC (2012) Collaboration with local people for sampling reptiles. In: McDiarmid RW, Foster MS, Guyer C, Gibbons JW, Chernoff N (Eds) Reptile Biodiversity Standard Methods for Inventory and Monitoring. University of California Press, Berkeley, 86–88.

Menezes FA, Fiorillo BF, Gonzalez RC (2015) Hooding behavior in *Erythrolamprus miliaris* Linnaeus, 1758 (Serpentes: Dipsadidae). Herpetology Notes 8: 291–293. https://www.biotaxa.org/hn/article/view/12261/13448

Mesquita PCMD, Passos DC, Borges-Nojosa DM, Cechin SZ (2013) Ecologia e história natural das serpentes de uma área de Caatinga no nordeste brasileiro. Papéis Avulsos de Zoologia 53: 99–113. https://doi.org/10.1590/S0031-10492013000800001

Morato SAA (2005) Serpentes da Região Atlântica do Estado do Paraná, Brasil: Diversidade, Distribuição e Ecologia. PHd Thesis. Universidade Federal do Paraná, Paraná, Brazil.

Moura-Leite JC, Bernils RS, Morato SAA, Langone JA (2003) *Echinanthera cephalostriata* ncn diet. Herpetological Review 34: 149.

Myers N, Mittermeier RA, Mittermeier CG, da Fonseca GAB, Kent J (2000) Biodiversity hotspots for conservation priorities. Nature 403: 853–858. https://doi.org/10.1038/35002501

Nogueira, CC, Alencar JPSV, Argolo AJS, Arredondo JC, Arzamendia V, Azevedo JA, Barbo FE, Bérnils RS, Bolochio BE, Borges-Martins M, Brasil-Godinho M, Braz H, Buononato M, Cisneros-Heredia DF, Colli GR, Franco FL, Giraudo A, Guedes T, Hoogmoed MS, Marques OAV, Montingelli GG, Passos P, Prudente ALC, Rivas G, Sanchez PM, Serrano FC, Silva Jr. NJ, Strüssmann C, Uhlig VM, Zaher H, Sawaya RJ, Martins M (2019) Atlas of Brazilian Snakes: verified point locality maps for mitigating the Wallacean shortfall in a megadiverse snake fauna. South American Journal of Herpetology 14(sp1): 1–274. https://doi.org/10.2994/SAJH-D-19-00120.1

Nogueira CC, Marques OAV (1998) Reprodução e hábitos alimentares de *Helicops carinicaudus* (Serpentes:Colubridae) na Mata Atlântica. XXII Congresso Brasileiro de Zoologia, 272 pp.

Oliveira JL (2001) Ecologia de três espécies de dormideira, *Sibynomorphus* (Serpentes: Colubridae). Master's Dissertation. Universidade de São Paulo, São Paulo, Brazil.

Oliveira ME, Martins M (2001) When and where to find a pitviper: activity patterns and habitat use of the lancehead, *Bothrops atrox*, in central Amazonia, Brazil. Herpetological Natural History 2: 101–110.

Pereira DN, Stender-Oliveira F, Guimarães MR, Bérnils RS (2007) Distribution and habitat use of *Sordellina punctata* (Serpentes, Colubridae), with a new record from state of São Paulo, Brazil. The Herpetological Bulletin 100: 18–22.

Pizzatto L, Almeida-Santos SM, Marques OAV (2007) Biologia reprodutiva de serpentes Brasileiras. In: Nascimento LB, Oliveira ME (Eds) Herpetologia no Brasil II. Sociedade Brasileira de Herpetologia, Belo Horizonte, 201–221.

Pizzatto L, Cantor M, Oliveira JL, Marques OAV, Capovilla V, Martins M (2008) Reproductive Ecology of Dipsadine Snakes, with emphasis on South American Species. Herpetologica 64: 168–179. https://doi.org/10.1655/07-031.1

Pizzatto L, Marques OAV (2006) Interpopulational variation in reproductive cycles and activity of the water snake *Liophis miliaris* (Colubridae) in Brazil. Herpetological Journal 16: 353–361. http://www.ingentaconnect.com/contentone/bhs/thj/2006/00000016/00000004/art00003

Pontes JAL, Figueiredo JP, Pontes RC, Rocha CFD (2008) Snakes from the Atlantic rainforest area of Serra do Medanha, in Rio de Janeiro state, southeastern Brazil: a first approximation to the taxocenosis composition. Brazilian Journal of Biology 68: 601–609. https://doi.org/10.1590/S1519-69842008000300018

Pontes JAL, Pontes RC, Rocha CFD (2009) The snake community of Serra doMendanha, in Rio de Janeiro State, southeastern Brazil: composition, abundance, richness and diversity in areas with different conservation degrees. Brazilian Journal of Biolology 69: 795–804. https://doi.org/10.1590/S1519-69842009000400006

Pough FH (1988a) Mimicry and related phenomena. In: Gans C, Huey RB (Eds) Biology of the Reptilia. Alan R. Liss, New York, 153–234.

Pough FH (1988b) Mimicry of vertebrates: are the rules different? In: Brower LP (Ed.) Mimicry and the Evolutionary Process. Univ. Chicago Press, Chicago, 67–102. https://doi.org/10.1086/284767

Proctor JB (1923) On a new genus and species of Colubrinae snakes from SE Brazil. Magazine of Natural History 9: 227–230. https://doi.org/10.1080/00222932308632844

Roberto IJ, Brito L, Cascon P (2011) Temporal and spatial patterns of reproductive activity in *Rhinella hoogmoedi* (Anura: Bufonidae) from a tropical rainforest in Northeastern Brazil, with the description of its advertisement call. South American Journal of Herpetology 6: 87–97. https://doi.org/10.2994/057.006.0207

Ribeiro MC, Metzger JP, Martensen AC, Ponzoni FJ, Hirota MM (2009) The Brazilian Atlantic Forest: How much is left, and how is the remaining forest distributed? Implications for conservation. Biological Conservation 142: 1141–1153. https://doi.org/10.1016/j.biocon.2009.02.021

Rodrigues MG (2008) *Chironius exoletus* (common whipsnake): Prey and Possible Diet Convergence. The Herpetological Bulletin 105: 41–42.

Roze JA (1996) Coral snakes of the Americas: Biology, identification and venoms. Krieger Publishing Company, Malabar, Florida, 328 pp.

Sawaya RJ, Marques OAV, Martins M (2008) Composition and natural history of a Cerrado snake assemblage at Itirapina, São Paulo State, southeastern Brazil. Biota Neotropica 8: 127–149. https://doi.org/10.1590/S1676-06032008000200015

Sazima I (1989) Feeding behavior of the snail-eating snake *Dipsas indica*. Journal of Herpetology 23(4): 464–468. https://doi.org/10.2307/1564072

Sazima I (1992) Natural history of the jararaca pitviper, *Bothrops jararaca*, in Southeastern Brazil. In: Campbell JA, Brodie ED (Eds) Biology of the pitvipers. Selva Publ, Tyler, Texas, 199–216.

Sazima I, Manzini PR (1995) As cobras que vivem numa reserva florestal urbana. In: Morellato PC, Leitão Filho HF (Eds) Ecologia e Preservação de uma Floresta Tropical Urbana. Ed. Unicamp, Campinas, 78–119.

Sazima C, Strüssmann I (1990) Necrofagia em serpentes brasileira: Exemplos e previsões. Revista Brasileira de Biologia 50: 463–468. https://doi.org/10.2307/1564072

Sena MA (2007) Levantamento da fauna e estudo cromossômico de algumas espécies de Reptilia, Squamata, do município de Cananéia, SP. Master's Dissertation, São Paulo, Brazil: Universidade de São Paulo.

Seigel RA, Ford NB (1987) Reproductive ecology. In: Seigel RA, Collins RA, Novak SS (Eds) Snakes: Ecology and Evolutionary Biology. Macmillan Publishers, New York, 210–252. https://doi.org/10.2307/1445695

Silva VX, Rodrigues MT (2001) *Xenodon neuwiedii* (Quiriripitá). Diet. Herpetological Review 32: 188.

Strüssmann C, Sazima I (1993) The snake assemblage of the Pantanal at Poconé, western Brazil: faunal composition and ecological summary. Studies on Neotropical Fauna and Environment 28: 157–168. https://doi.org/10.1080/01650529309360900

Toledo LF, Ribeiro RS, Haddad CFB (2007) Anurans as prey: an exploratory analysis and size relationships between predators and their prey. Journal of Zoology 271: 170–177. https://doi.org/10.1111/j.1469-7998.2006.00195.x

Torello-Viera, NF, Marques OAV (2017) Daily Activity of Neotropical Dipsadid Snakes. South American Journal of Herpetology 12: 128–135. https://doi.org/10.2994/SAJH-D-16-00023.1

Vanzolini PE, Ramos-Costa AMM, Vitt L (1980) Répteis das Caatingas. Academia Brasileira de Ciências, Rio de Janeiro, 313 pp. https://doi.org/10.5962/bhl.title.109659

Vitt LJ (1992) Diversity of reproductive strategies among Brazilian lizards and snakes: the significance of lineage and adaptation. In: Hamlett WC (Ed.) Reproductive Biology of South American Vertebrates. Springer-Verlag, New York, 135–149. https://doi.org/10.1007/978-1-4612-2866-0_10

Vitt LJ, Vangilder LD (1983) Ecology of a snake community in Northeastern Brazil. Amphibia-Reptilia 4: 273–296. https://doi.org/10.1163/156853883X00148

Winne CT, Willson JD, Gibbons JW (2006) Income breeding allows an aquatic snake *Seminatrix pygaea* to reproduce normally following prolonged drought-induces aestivation. Journal of Animal Ecology 75: 1352–1360. https://doi.org/10.1111/j.1365-2656.2006.01159.x

Yanosky AA, Dixon JR, Mercolli C (1996) Ecology of the snake communityat El Bagual Ecological Reserve, Northeastern Argentina. Herpetological Natural History 4: 97–110.

Young BA, Kardong KV (2010) The functional morphology of hooding in cobras. Journal of Experimental Biology 213: 1521–1528. https://doi.org/10.1242/jeb.034447

Supplementary material 1

Specimen identifications

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Explanation note: List of collected and/or examined specimens and their identifications and museums.

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