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New Cases of Teratology, Albinism, Abnormal Pigmentation, Gynandromorphism, and Injury Healing in Scorpions (Arachnida: Scorpiones)

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Abstract: Eighteen new cases of teratology and other abnormalities within scorpions are presented, representing new cases of metasomal duplication, mesosomal anomaly, telson anomaly, albinism, and abnormal pigmentation. Furthermore, recently published literature on other scorpion anomalies are tabulated to update the recent 2023 checklist of scorpion teratology which charted all known literature up to the aforementioned work.

Keywords: anomaly; deformity; congenital; intersexuality; chimera

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1. Introduction

Scorpions are amongst the most recognisable animals, possessing chelae (“claws”), a metasoma (“tail”), and eight legs, and have been recorded in human culture for millennia. Anomalies in scorpions have been reported formally in print since the work of Pliny the Elder in the year 70 AD [1] and by the end of 2023, 82 works [2–18] had been published in total [19]. Many early works reported single specimens [1–4], although many later works compiled many more cases within their respective publications [8,10,11,19]. A complete history and tabulation of the types of teratology found in scorpions was provided by Sherwood and Armas [19], to whom we direct the reader for comprehensive information. In this work, we provide 18 new cases of teratology and other anomalies found in scorpions, encountered during our ongoing research. Furthermore, all other publications in 2024 regarding scorpion teratology known to us, in addition to one work which was overlooked by Sherwood and Armas [19], are tabulated (Table 1).

Table 1. Additions to the list of anomalies in scorpions in the published literature, adding all new records from 2024 and one work overlooked by Sherwood and Armas [19].

Work	Family	Taxon	Life Stage and Sex	Anomaly/Anomalies
Neo et al. (2022) [16]	Scorpionidae	*Heterometrus longimanus* (Herbst, 1800)	Adult ♀	Malformed median ocelli and their peripheral structure.
Zouatine et al. (2024) [17]	Buthidae	*Androctonus amoreuxi* (Audouin, 1826)	Adult ♀ Adult ♀	Regenerated (hook-like) pedipalp tibia. Enlarged right chelicera.
Yağmur et al. (2024) [18]	Scorpionidae	*Scorpio kruglovi* Birula, 1910	Subadult ♀	Regenerated (node-like) pedipalp tibia.

2. Materials and Methods

Specimens reported herein were observed and photographed (using commercially available cameras) by the respective author(s), indicated by their initials. General layout and methods follow Sherwood and Armas [19]. Records are derived either from the respective authors directly or via users on iNaturalist. Records on iNaturalist were found during manual searches of all scorpion photographs on the website, looking for cases of obvious abnormalities; when found, a note was made, and the photographer was contacted via iNaturalist to ask for permission for the use of their data. Scorpions collected from the wild were opportunistically collected by hand; a summary of specimens and localities is provided in Table 2. On selected plates where anomalies may not be immediately obvious, red arrow(s) are used to indicate the abnormal morphology. Abbreviations: IAD = inner accessory denticle; ID = inner denticle; LO = lateral ocellus(i); MD = median denticle; MO = median ocellus(i); SAT = subaculear tubercle of telson; Ss = spinule-like structure; PTC = pectinal tooth count; P-Vt = ventral trichobothria of pedipalp patella; OD = outer denticle.

Table 2. Summary of locality information and current repositories of specimens reported in this work.

Taxon	Life Stage and Sex	Locality (If Wild)	Date of Initial Collection, Observation, or Acquisition	Status	Current Repository
Androctonus aeneas C. L. Koch, 1839	From birth to 5th-instar scorplings	N/A	Born in captivity	Preserved in alcohol	MS private collection, Germany
Androctonus australis (Linnaeus, 1758)	Adult ♀	N/A	Born in captivity in 2022	Alive	MS private collection, Germany
Androctonus bicolor (Ehrenberg, 1828)	Adult ♀	N/A	Captive specimen, observed on 30 August 2023 when alive	Preserved as dried specimen	VT private collection, China
Buthus pyrenaeus Ythier, 2021	Adult ♀?	Occitanie, Pyrénées-Orientales, Serdinya	Observed on 27 May 2024	N/A, not collected	N/A, not collected
Centruroides sculpturatus Ewing, 1928	Adult ♀	Carrie Nation Trailhead in Madera Canyon, Santa Cruz County, Arizona	Collected on 14 August 2016	Preserved in alcohol	JK private collection, United States
Hemiscorpius lepturus Peters, 1861	Immature ♀	N/A	Born in captivity in 2023	Alive	MS private collection, Germany
Hottentotta buchariensis (Birula, 1897)	2nd-instar scorpling	N/A	Observed in May 2017, born in captivity	Preserved in alcohol	MS private collection, Germany
Hottentotta zagrosensis Kovařík, 1997	Adults and immatures	N/A	Born in captivity in 2023	Alive	MS private collection, Germany
Leiurus jordanensis Lourenço, Modry & Amr, 2002	Adults and immatures	N/A	Born in captivity in 2023	Alive	MS private collection, Germany
Lychas cf. *variatus canopensis*	Immature	Wau, Papua New Guinea	Observed on 15 June 2022	N/A	N/A, not collected
Lychas aff. *marmoreus*	Adult ♀	Victoria, Australia	Observed on 2 August 2023	N/A	N/A, not collected
Nebo whitei Vachon, 1980	From birth to 9th instar	Wadi Darbat, Dhofar, Oman	Born in captivity in April 2022	Preserved in alcohol	MS private collection, Germany
Parabuthus capensis (Ehrenberg, 1831)	Gynandromorphic adult	N/A	Unknown	Dead but not preserved	N/A

Table 2. *Cont.*

Taxon	Life Stage and Sex	Locality (If Wild)	Date of Initial Collection, Observation, or Acquisition	Status	Current Repository
Parabuthus capensis (Ehrenberg, 1831)	Immature ♀	Kliphuis, Western Cape, South Africa	Observed on 3 January 2024	N/A	N/A, not collected
Scorpiops aff. *vachoni* (Qi, Zhu & Lourenço, 2005)	Adult ♀	Yunan, China	Observed on 24 July 2024	Preserved in ethanol	VT private collection, China
Tetratrichobothrius flavicaudis (De Geer, 1778)	Adult ♀	Lazio, Rome, Carpineto romano, Italy	Observed on 4 May 2024	Preserved in alcohol	VG private collection, Italy
Tetratrichobothrius flavicaudis (De Geer, 1778)	Adult ♀	Occitanie, Hérault, Montpellier, France	Observed on 3 June 2024	Preserved in alcohol	JT private collection, France
Tetratrichobothrius flavicaudis (De Geer, 1778)	Immature	Provence-Alpes-Côte d'Azur, Alpes-de-Haute-Provence, Dignes-les-Bains	Observed in 1987	Preserved in alcohol	JT private collection, France

3. Results

3.1. *Androctonus aeneas C. L. Koch, 1839 (Buthidae)*

Remarks. A captive-bred adult female of *Androctonus aeneas* C. L. Koch, 1839, owned by MS, produced a brood that contained amongst the scorplings two unusually coloured specimens. One exhibited partial leucism (Figure 1B), and the other was chimeric (Figure 1A,C–E): normally coloured in the left half and exhibiting partial leucism (excluding metasoma and telson) in the right half (Figure 1A–F). Partial leucism was identified given the extreme reduction in normal colouration (i.e., blackish brown) to a whitish hue. The retention of dark pigment in the ocelli of both specimens argues against recognising their anomaly as partial albinism. Partial leucism was not conspicuous in metasoma III–V in the former specimen and was most intense in its prosoma and pedipalps. Both specimens died at the fifth instar, not reaching adulthood like the normal scorplings (Figure 1F). The specimens are preserved in the private collection of MS.

3.2. *Androctonus australis (Linnaeus, 1758) (Buthidae)*

Remarks. A captive-bred adult female of this species (Figure 2A–D) was observed to have a total absence of pectines by MS. Its genital operculum and pectinal plates are not compromised. Its sex is determined based on the morphometrics of other body parts, particularly the chela. It remains alive (time of writing: November 2024) in the private collection of MS. Recently, a conspecific adult male was introduced to the enclosure in November 2024 by MS. Both specimens were receptive and immediately started the promenade a deux. After some hours of observation, they were left together overnight undisturbed in complete darkness. In the morning a flattened spermatophore could be found, which indicates a successful promenade a deux and fertilisation despite the missing pectines of the abnormal female.

Figure 1. Partial leucism in *Androctonus aeneas* C. L. Koch, 1839. (**A**,**C**–**E**) Chimeric specimen showing partial leucism on its right half and normal colouration on its left half ((**A**), fourth instar; (**C**–**E**), fifth instar). Leucism not extended to metasoma and telson. (**B**) Specimen (fourth instar) displaying partial leucism uniformly, with the extent decreasing towards metasoma III. (**F**) Normal fourth-instar juvenile showing brownish-black colouration. Photos by MS.

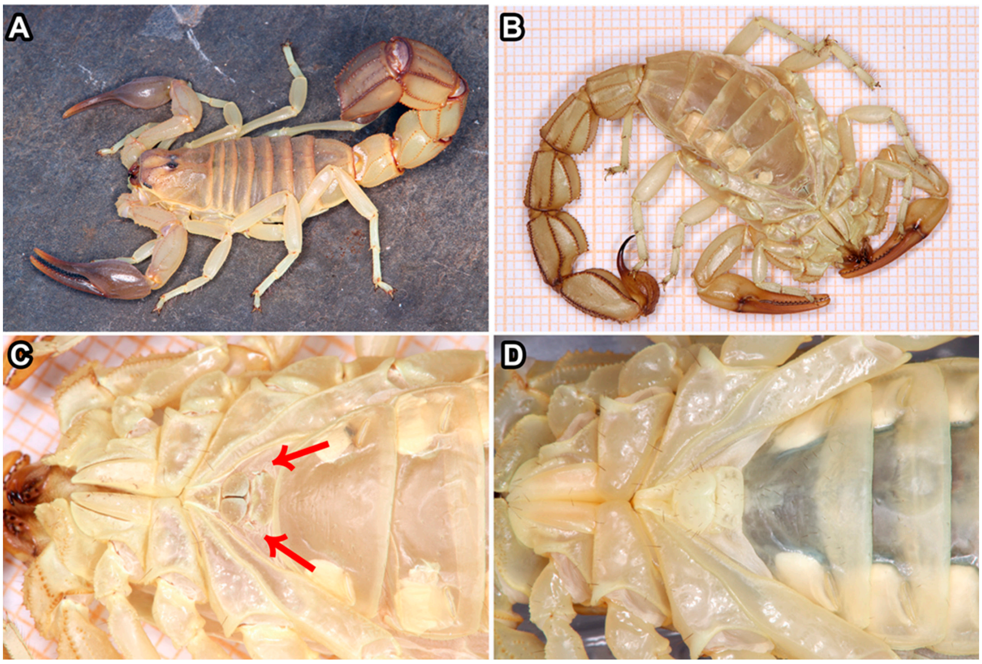

Figure 2. Complete loss of pectines in adult female of *Androctonus australis* (Linnaeus, 1758). (**A**,**D**) Specimen in vivo. (**B**,**C**) Exuvia. Arrows point to anomaly. Photos by MS.

3.3. Androctonus bicolor (Ehrenberg, 1828) (Buthidae)

Remarks. The author VT encountered an adult female specimen of *A. bicolor* with fluorescent lateral and median ocelli (Figure 3B–F). The specimen is a captive-bred individual purchased from a friend of the second author (Yizun Wang) in 2023. The specimen died in 2024 and was subsequently dissected, embalmed, and desiccated for inclusion in the dry specimen collection of VT.

The phenomenon of scorpion cuticle fluorescence has been extensively investigated and was recently discussed by Tang and Liu [20]. Several sclerotised metallic structures (e.g., aculeus, tarsal ungues, pedipalp, and cheliceral denticles) are known to be non-fluorescent. This opposite optical property also extends to the eyes and certain types of setae in normal scorpions, as well as their intersegmental membrane (likely due to different secreted substances on these surfaces; Hjelle in Polis [21]). The absence of fluorescence in the eyes of normal scorpions is most likely a consequence of the melanin granules present in the epidermis and retina that largely absorb incident light. However, the eyes of albino scorpions, albeit appearing more greyish under UV light, nonetheless hardly exhibit fluorescence compared to their surrounding cuticle (cf. [20] (Figures 11, 22 and 26)), probably owing to the lack of chemical compounds necessary for inducing UV-excited fluorescence emission. Accompanied herein for comparison is a normal specimen of *A. bicolor* with non-fluorescent but instead Prussian blue lateral and median ocelli (Figure 3A). Contrasting this with the abnormal female specimen, the eyes of the latter exhibit a comparable level of fluorescence with its surrounding cuticle, rendering them nearly indistinguishable. The lens of the median ocellus is discernible due to an inner structure that appears separated from this external transparent shield (Figure 3C,E,F), suggesting that the lens is unlikely to be the primary contributor to the observed fluorescence, if at all.

To conjecture the possible cause accounting for the phenomenon, it would be logical to first comprehend the mechanisms underlying the fluorescence manifestation. Scorpions are known to recover their fluorescence after ecdysis or prolonged UV exposure that causes regional photobleaching (reduction in fluorescence intensity due to cumulative damage), with recovery rates varying by area according to Liu et al. [22]. This indicates that the fluorescence synthesis is dynamic, and its intensity is susceptible to change, as well as explaining why freshly moulted specimens show weak fluorescence (and non-fluorescent in first newborns). Recent studies conducted on post-ecdysis scorpions by Li et al. [23] showed that fluorescent substances are synthesised in the glands of the digestive tract within the mesosoma and then transported via coelomic fluid to and concentrated in the newly formed layer of exoskeleton. Personal observations by DS and VT, along with the earlier report by Cloudsley-Thompson [24] (p. 187), revealed that the embalming fluid could be "dyed" by the scorpion specimen and become fluorescent under UV light (e.g., Figure 3G,H). It remains unclear whether these fluorescent solutes represent a liquid-state form of scorpion fluorescence or if the fluid acted as a solvent, extracting these substances from the cuticle. In any case, in tandem with the previous findings derived from post-ecdysis juveniles, the fluorescence in the abnormal *A. bicolor* could putatively be explained by the ambulatory nature of those substances that inadvertently imbued the ocular structures.

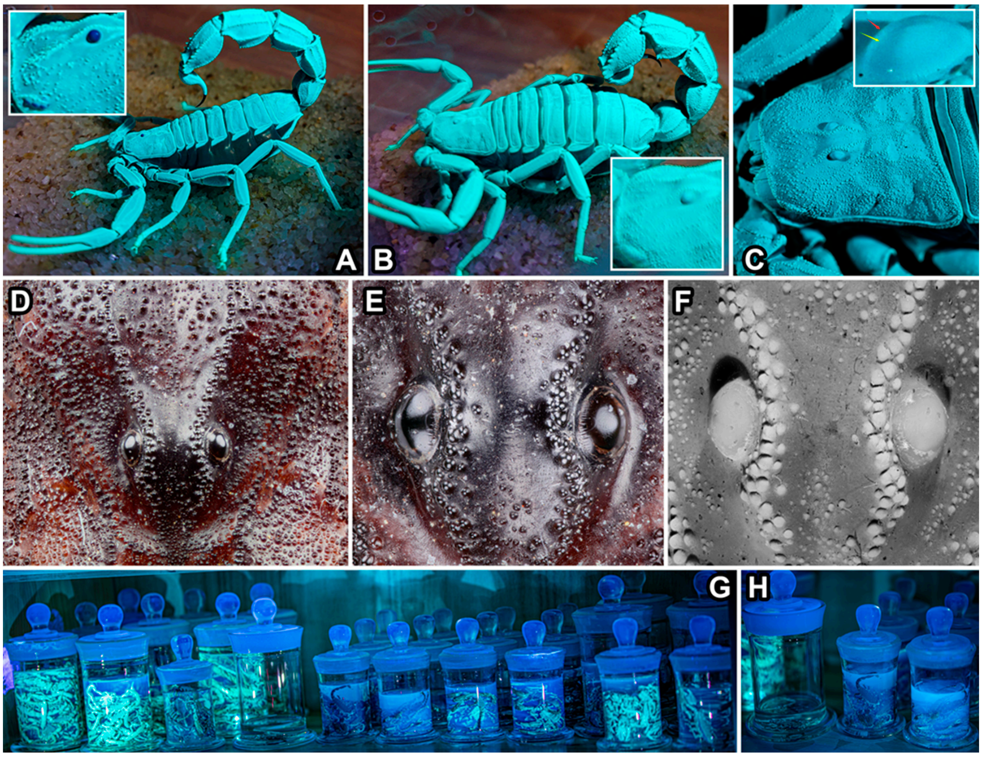

Figure 3. *Androctonus bicolor* Ehrenberg, 1828. (**A**,**B**) Comparison of optical properties of lateral and median ocelli under UV light (365 nm) between a normal juvenile (**A**) and an abnormal adult female (**B**) specimen, in vivo habitus. (**C**) Close-up of abnormal female under UV light in vivo habitus. (**D**–**F**) Median ocelli of abnormal female under white (**D**,**E**) and UV (**F**) lights post-mortem (desiccated specimen). (**G**,**H**) Ethanol-preserved specimens with fluid showing fluorescence. The yellow and red arrows in the inset of Figure 3C show the gap between the external and internal contours, where fluorescence is limited to beneath the internal contours. Note that the non-fluorescent ethanol in the left jar in Figure 3H was introduced the day when the photo was taken. Photos by VT.

It remains unknown whether this trait is congenital or postnatal, since the specimen was not observed from its birth. Despite the noted anomaly, the specimen showed no ethological eccentricity, demonstrating full capability of light perception, both under UV and white light. This case remains notable due to its uniqueness. Superficially similar cases have been documented in various taxonomic studies (e.g., [25] (Figure 4A); [26] (Figure 15E); [27] (Figures 168 and 169); [28] (Figure 6F); [29] (Figure 3); [30] (Figures 67, 76, 77 and 70–80); [31] (Figures 839 and 855)). However, we caution against placing undue credence on preserved specimens. Preservation processes can induce physical and chemical changes in specimens, which have not been systematically studied. For instance, observed anomalies could be attributed to a reduction in fluorescence of the surrounding cuticle or an increase in the fluorescence of the ocelli, resulting in similar apparent intensities. Additionally, taxa with naturally low fluorescence in their cuticle (e.g., *Chaerilus* Simon, 1877; cf. [31] (Figures 865, 866, 874 and 875)) might exhibit such variations due to a lower level of contrast ratio of fluorescence intensity or inherently brighter median eyes under UV light, which would not be considered anomalous within the genus. UV fluorescence studies should ideally be conducted on live or freshly preserved specimens to avoid potential misinterpretations.

3.4. *Buthus pyrenaeus* Ythier, 2021 (Buthidae)

Remarks. A likely adult female of *Buthus* cf. *pyrenaeus* was observed by the authors JT and LL on 27/May 2023 in France (full data: Occitanie, Pyrénées-Orientales, Serdinya; 42°34′02.0″ N 2°18′18.8″ E; under rocks near a dirt road in a mixed evergreen forest dominated by *Quercus ilex*), showing a deformation on the anterior margin of the prosoma (Figure 4A–D). This feature is unlikely teratological in nature, and we hypothesise it is the result of recovery from an old injury, as suggested by the asymmetrical shape of the indentation, which also seems to end in scar tissue (Figure 4D). In that case, the smoothed-out features of this deformity also suggest that the specimen underwent ecdysis following the injury, allowing for partial regeneration of the prosoma. The specimen was not collected.

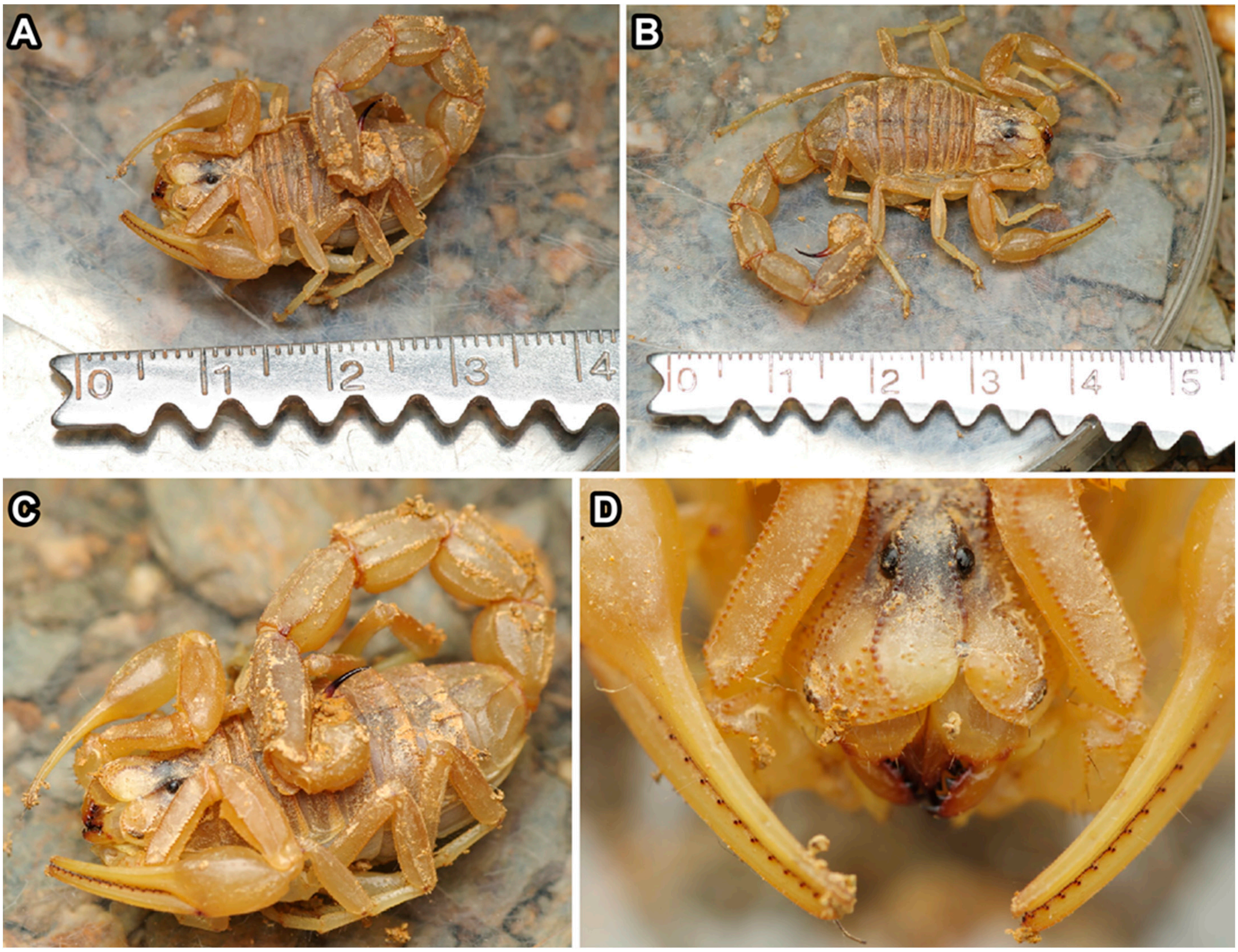

Figure 4. *Buthus* cf. *pyrenaeus* Ythier, 2021. (**A**,**B**) Habitus, dorsal view. (**C**) Habitus, lateral view. (**D**) Close-up Photos by JT and LL.

3.5. *Centruroides sculpturatus* Ewing, 1928 (Buthidae)

Remarks. The author JK, along with B.J. Stacey, observed a specimen of *C. sculpturatus* with two metasomas and a deformed chela on the evening of 14 August 2016 at the Carrie

Nation Trailhead in Madera Canyon, Santa Cruz County, Arizona, located using a blacklight flashlight. Recognising it as an exceptional specimen, they carefully collected it in a vial for the purpose of continued observation of it in captivity. The individual had a fully formed left chela, but the right chela had only a partially formed fixed finger, which was virtually unusable (JK pers. obs.).

The specimen was placed in a 12 × 8 inch glass terrarium with a dry, sandy substrate and a hiding spot on 15 August 2016. The next day, drops of water were placed on the sand, and the scorpion moved over top of the water and laid down in it but did not drink. A shallow water dish was added shortly thereafter, with occasional misting as needed to maintain proper humidity. On 17 September 2016, the enclosure was reconfigured with coconut husk, a substrate more closely mimicking its natural habitat. That evening, live insects were offered as food, including a winged termite (*Coptotermes formosanus*) and a few scarabaeoid beetles, which were not consumed. The following evening, a small noctuid moth of undetermined species was offered, and when observed the next morning, just four wings of the moth remained, along with the beetles and termite, which were removed from the enclosure. On 20 August 2016, a fly of the genus *Lucilia* was offered with one wing removed to assist the scorpion in its capture. However, the scorpion immediately and aggressively pursued the fly, grabbed it with its left (fully formed) chela, with the other being used as a prod, and then quite accurately stung it with both telsons nearly simultaneously. Throughout its time in captivity, it was offered a myriad of insect prey, mostly small Lepidoptera collected under lights, but also flies, crickets, and others, including another termite, which this time it did consume. The specimen readily took such prey.

The specimen's use of its metasomas was observed extensively while in captivity, and it was clear that they were each fully and seemingly equally functional in every manner. They were sometimes held over the body, sometimes both off to the side, and sometimes one up with the other down. Occasionally, while consuming prey, it crossed them.

On 14 October 2016, a cricket was presented, and the scorpion made a limited attempt at capturing it but did not succeed or re-attempt. The specimen thereafter refused prey items for 12 days, leading up to its first moult in captivity on 26 October 2016. It underwent ecdysis without issue, retaining both metasomas and, surprisingly, adding some length to the anomalous fixed finger on the right chela. It resumed feeding on 31 October 2016 but used only its left chela to hold the prey while it was consumed alive and did not use its telsons, perhaps due to it continuing to harden its exoskeleton following the moult. Following cuticle hardening, it resumed use of the telsons in the same manner observed prior to ecdysis.

Over the next two years, it continued to thrive in its enclosure, feeding readily; no further moults were attempted, and the specimen died suddenly on 13 September 2018 of unknown causes. The specimen (Figure 5A–E) is preserved in alcohol in the personal collection of JK.

3.6. *Hemiscorpius lepturus* Peters, 1861 (Hemiscorpiidae)

Remarks. A captive-bred immature female of *H. lepturus*, a species originating from Iran, currently kept in the private collection of MS shows tergal division on its fourth tergite (Figure 6A–C). The gap is relatively wide, and the opposing sclerites are approximately axisymmetric in shape. It remains alive (time of writing: November 2024) and is continuing to be reared.

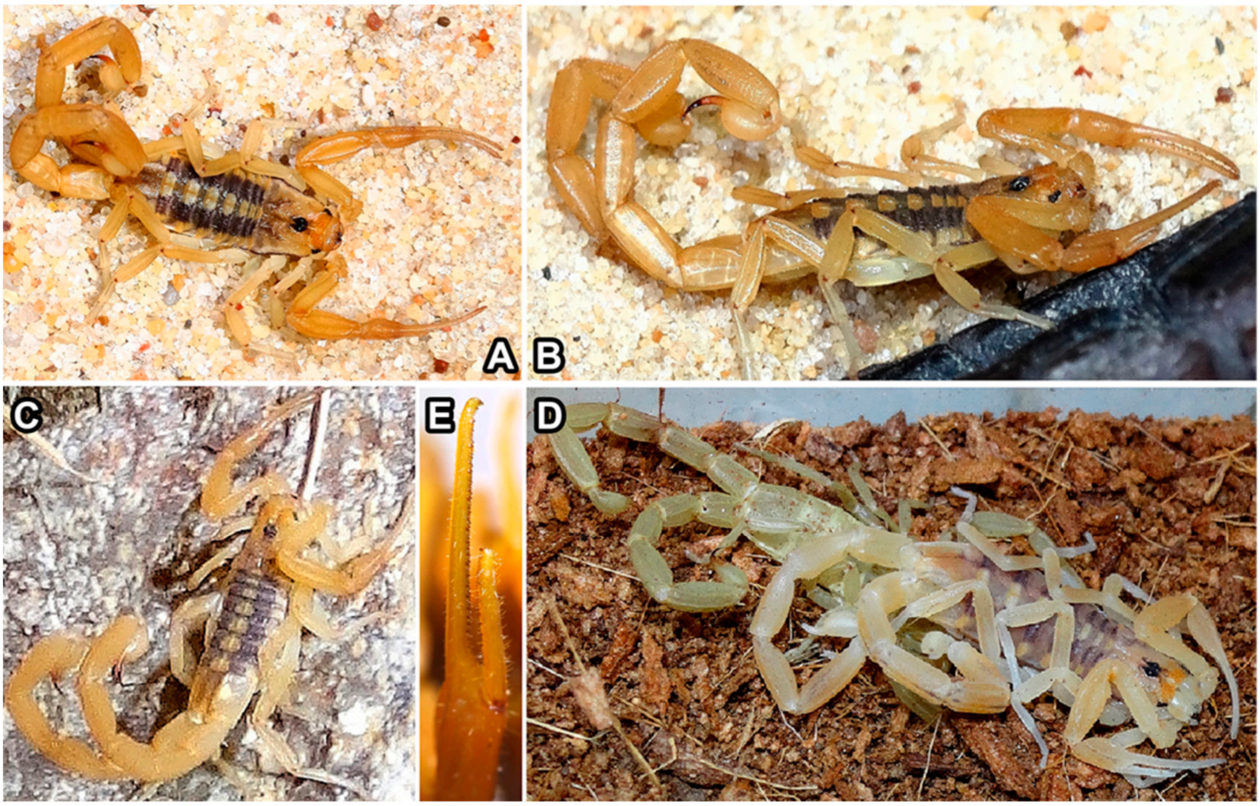

Figure 5. *Centruroides sculpturatus* Ewing, 1928, adult female with metasomal duplication and chelal anomaly. (**A**–**C**) Habitus in vivo. (**D**) Habitus in vivo following ecdysis, with exuvia underneath specimen. (**E**) Close-up of deformed chela in specimen following preservation. Photos by JK.

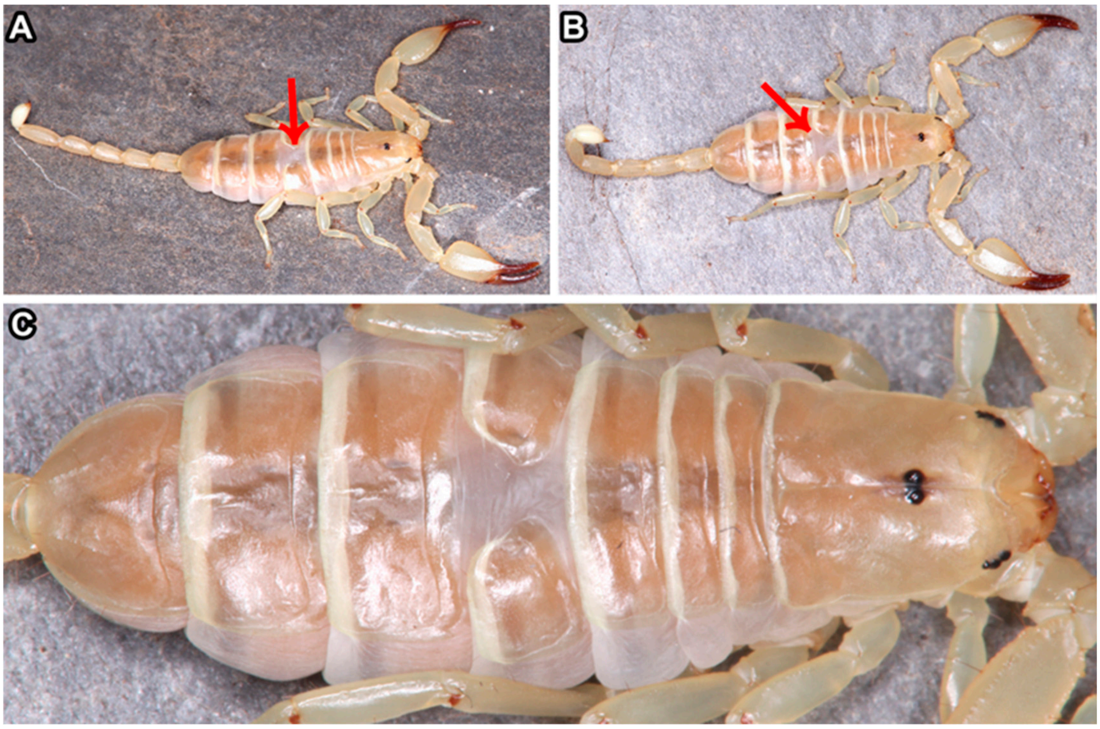

Figure 6. Immature female *Hemiscorpius lepturus* Peters, 1861, showing wide tergal division on its fourth tergite (**A**–**C**). Arrows indicate anomaly. Photos by MS.

3.7. Hottentotta buchariensis (Birula, 1897) (Buthidae)

Remarks. The most striking case of scorpion teratology we have ever observed is of a captive-bred specimen of this Afghan species originally reared by scorpion breeder Melanie Kaminski in May 2017. In contrast to typical scorpions with monstra duplicia, which have two metasomas or opisthosomas, this specimen (Figure 7A,B) has joined prosomal shields with two sets of median eyes, four sets of lateral eyes, and two sets of chelicerae. Additionally two pedipalps were joined as one with two tibiae (fixed fingers) and the two tarsi (moveable finger) fused into one. The outer pedipalps were functional, but the middle fused one was not fully moveable. The scorpion seemed to be able to move this whole pedipalp at the joint between the prosoma and coxa up and down easily, but only slightly left and right. The other joints between the coxa and chelae remained flexible but were not controllable by the scorpion when pushed to the container walls or touched by its extremities but bent straight automatically when freed. No abnormalities were found on the legs nor the ventral prosoma. The specimen died during the second instar, never taking any food during its life, and is preserved in the private collection of MS.

Figure 7. *Hottentotta buchariensis* (Birula, 1897) showing duplicated prosoma and a fused pedipalp. (**A**) Habitus in vivo at the second instar. (**B**) Habitus in vivo at the first instar (the one near the femur-patella joint of the fourth leg of the mother scorpion). Arrow indicates anomalous specimen amongst normal siblings. Photos by and courtesy of Melanie Kaminski (used with permission).

3.8. Hottentotta zagrosensis Kovařík, 1997 (Buthidae)

Remarks. After captively breeding this Iranian species for many years, scorpion breeder Giorgio Molisani observed a brood containing albino scorplings (Figure 8A–D). These showed no other abnormalities, and he was able to raise them to adulthood. The subsequent pairing of two albino specimens together produced wholly albino scorplings. Live specimens are still maintained at the time of writing by Molisani and MS. Complete albinism has been recorded three times previously in scorpions to our knowledge, first by Locket [32], then by Teruel and Turiel [33], and most recently by Tang and Liu [20]. In addition, a partial variation was reported by Armas and Cubás-Rodríguez [14]. A case of hypomelanism (per [20] originally documented as leucism), a distinctly different biological phenomenon, was reported by Lira et al. [34].

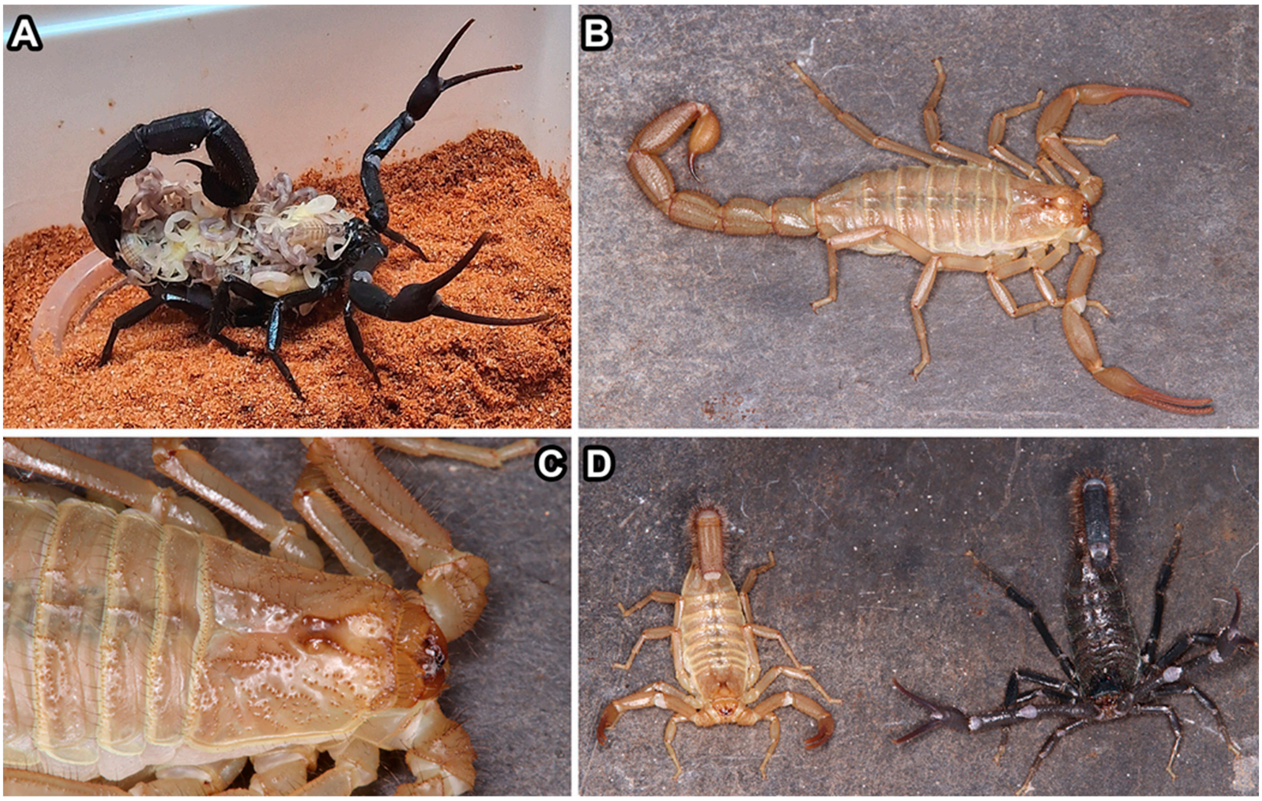

Figure 8. *Hottentotta zagrosensis* Kovařík, 1997. (**A**) Female carrying a brood of freshly moulted offspring with some showing albinism. (**B**,**C**) An exemplar subadult male albino specimen. (**D**) Comparison of the albino subadult male with a normal subadult male. Photos by MS.

3.9. Leiurus jordanensis Lourenço, Modry & Amr, 2002 (Buthidae)

Remarks. Similarly to *Hottentotta zagrosensis*, Giogio Molisani observed albinism in captive-bred specimens of *L. jordanensis*, and he and MS maintained specimens for further investigation (Figure 9A–E). Interestingly, although both *H. zagrosensis* and *L. jordanensis* are normally dark-coloured, the albino phenotype of *H. zagrosensis* is noticeably more brownish, exhibiting greater infuscation.

Albino scorpions typically display colouration reminiscent of their normal exuviae. If the exuvia colour of normal individuals dictates the hue in albino counterparts, it would be intriguing to observe the albino phenotypes in dark-coloured *Orthochirus* species, whose exuviae retain dark pigment on metasomal segments and telson (Figure 9F). However, the exuviae of both normal *L. jordanensis* and *H. zagrosensis* are pale yellow (G. Molisani pers. obs.), a trait shared by albino *L. jordanensis* (MS pers. obs.). The pale brown colouration in albino *H. zagrosensis* hence indicates some retention of infuscation. On the other hand, although albino *H. longimanus* were observed to display a much brighter colouration than the exuvia of their normal counterparts, they achieved a similar hue until they partially regained their melanin at adulthood [20] (Figures 72–77). The colouration of scorpion exuvia has not been systematically studied. Exploring the mechanisms behind the various extents of infuscation retention in exuvia across different taxa could shed light on the apparent regain of infuscation observed in albino *H. zagrosensis* and *H. longimanus*.

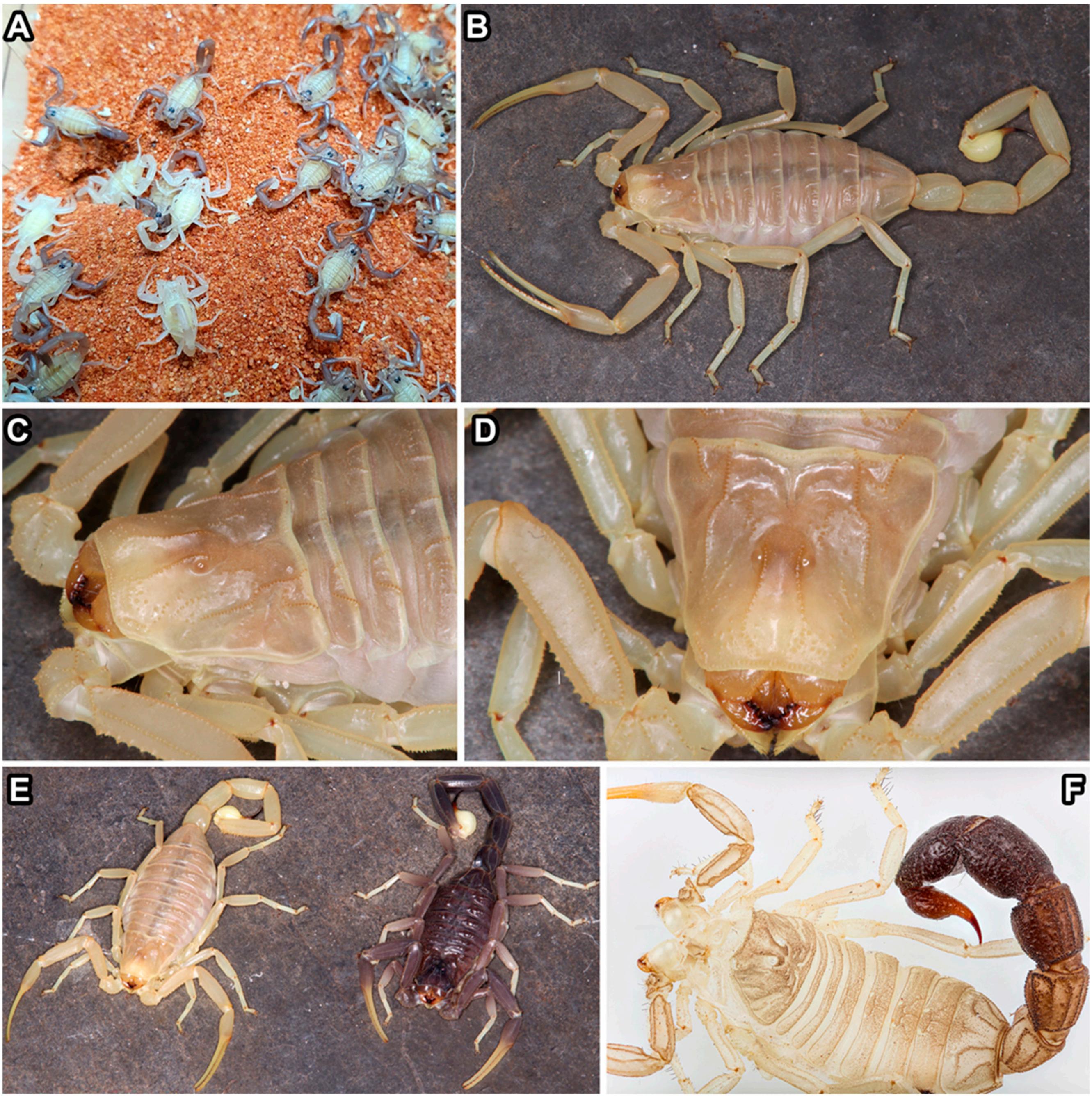

Figure 9. *Leiurus jordanensis* Lourenço, Modry & Amr, 2002. (**A**) A group of juveniles at the second instar, with some showing albinism. (**B**–**D**) An exemplar subadult female albino specimen. (**E**) Comparison of the albino subadult female with a normal subadult female. (**F**) Exuvia of a juvenile *Orthochirus* sp. from Egypt, showing normal exuvial pigmentation. Photos by MS.

3.10. Lychas spp. (Buthidae)

Remarks. We document two species of *Lychas* with mesosomal teratology characterised by a short longitudinal median division on tergites, connected by a membrane

(Figure 10A,B). Accurate species-level identification from photographs (neither specimen was collected) is not feasible due to the need for a global revision of the genus. Based on morphology and geographic provenance [35,36], we tentatively refer to them as *L.* cf. *variatus canopensis* (Figure 10A) and *L.* aff. *marmoreus* (Figure 10B). The juvenile *L.* cf. *variatus canopensis* was observed by Philipp Hoenle in Usino-Bundi (Madang, Papua New Guinea), near Wau (5°44′25.3″ S 145°19′52.0″ E; iNaturalist record 124092783). For comparison, the type locality of *L. variatus canopensis* Lourenço & Qi, 2007, is also in Madang Province, near Kawe (5°01′ S 145°45′ E). The adult female *L.* aff. *marmoreus* was observed by Reiner Richter in Stawell (Victoria, Australia), near Mokepilly (37°05′14.9″ S 142°37′15.9″ E; iNaturalist record 177062894). Both specimens exhibited an unambiguous cuticular division on at least tergites II–III, whereas in *L.* aff. *marmoreus*, the first tergite was additionally cleaved by a larger gap.

Figure 10. *Lychas* C. L. Koch, 1845 species with tergal anomalies. (**A**) Juvenile *Lychas* cf. *variatus canopensis* from Usino Bundi (Madang, Papua New Guinea) showing wide longitudinal tergal division on tergites II–III ((**A**) photo by and courtesy of Philipp Hoenle, https://www.inaturalist.org/observations/124092783 (accessed on 15 October 2024); CC-BY-NC, http://creativecommons.org/licenses/by-nc/4.0/ (accessed on 15 October 2024). (**B**) Adult female *Lychas* aff. *marmoreus* from Stawell (Victoria, Australia) showing irregular longitudinal tergal division on tergites I–III ((**B**) photo by and courtesy of Reiner Richter, https://www.inaturalist.org/observations/177062894 (accessed on 15 October 2024); CC-BY, http://creativecommons.org/licenses/by/4.0/ (accessed on 15 October 2024). Arrows indicate anomalies.

A drop-shaped depression can be observed in the juvenile *L.* cf. *variatus canopensis*, spanning from the posterior carapace to tergite IV, with the tergal fissure located in the centroid. The depression was manifested as the first half of mesosoma surface concaving towards the fissure, with surrounding tergites curving inwardly. Affected tergites ranged from tergites I–IV, with tergites II–III separated entirely, resulting in two opposing pairs of lobiform tergites directed at the fissure. The first tergite was distorted in a backward direction along its medial axis, with a V-shaped fracture on its pretergite and a posttergite appearing as two halves that tapered and converged towards each other. The fourth tergite was influenced to a lesser extent, slightly malformed anteriorly. The depression also led to a triangular region on the carapace, slanting downward to the posterior margin where a V-shaped medial cleft was present (cf. [37] (Figure 7) for comparison with a normal carapacial morphology in a similar species). The posterior margin of the carapace was deformed, resembling the upper portion of a heart shape, where a pair of smooth arcs converge downwardly into a sharp apex.

The teratology of the adult female *L.* aff. *marmoreus* seems to be primarily confined to the first three tergites. More accurately, tergites I–II featured a much larger gap than the one that divided tergite III, but the two gaps were connected and formed a continuous fissure. This fissure was characterised by its asymmetry when referencing the flanking tergites (which were derived from an integral tergite divided into left and right halves). Defining the margin that faced the fissure as the internal margin of the malformed tergite, the internal margins of right tergites I–II were more external than the left pair. In addition, the internal margins of the left pair were smoother and more lobiform. The gap that separated tergite III, however, took on a flared profile with a narrower anterior portion and a V-shaped cleft on the original posterior margin.

3.11. Nebo whitei Vachon, 1980 (Diplocentrididae)

Remarks. A captive-bred adult female of this species from Oman owned by MS exhibits monstra duplicia. The specimen(s) are conjoined directly behind the prosoma, forming a Y-shaped first tergite (Figure 11A–D), which leaves it with two opisthosomas. It has eight legs but two genital opercula; both sides are female. Its general movement was surprisingly normal, and even its climbing abilities were nearly at the same level as normally seen in this species (MS pers. obs.). A coordination of the two metasomas did not seem to be possible, and even with a great feeding response, it was unable to hunt down prey with the use of venom. The specimen underwent ecdysis without incident, but successive ecdyses showed a smaller respective size increase compared to normal specimens. The specimen survived until the ninth instar, dying two days after ecdysis, remaining juvenile until its death. It is preserved, along with all its exuviae (Figure 11E), in the private collection of MS.

3.12. Parabuthus capensis (Ehrenberg, 1831) (Buthidae)

Remarks. We record two anomalies in *P. capensis* (Figure 12A–E). The first case involves a captive-bred specimen displaying intersexuality andgynandromorphism (Figure 12A–C). This specimen, previously owned by a Chinese scorpion breeder and purchased from a Chinese seller, died in May 2024 (Yizun Wang pers. comm. to VT), precluding first-hand examination. Intersexuality and gynandromorphy has been reported in a few scorpion species by some previous authors: *Tityus bahiensis* (Perty, 1833) [5]; *Brachistosternus pentheri* Mello-Leitão, 1931 [38,39]; *Cazierius gundlachii* (Karsch, 1880) and *Bioculus comondae* Stahnke, 1968 [9]; *Alayotityus delacruzi* Armas, 1973, and *Tityopsis inaequalis* (Armas, 1974) [40,41]; *Bothriurus araguayae* Vellard, 1934 [39], and *Mesomexovis punctatus* (Karsch, 1879) [13]. Notably, photos of the gynandromorph *P. capensis* reveal a chromatic asymmetry along the longitudinal axis of the mesosoma, where the left half (yellow) is conspicuously brighter than the right half (orange). The yellow pigmentation extended to the carapace, forming a subtriangular configuration, with its inner bound delimited by the MO-LO distance. An irregular band of intermediate colouration was evident along this boundary. Given that the predominant hue of the specimen was orange, the yellow pigmentation was considered anomalous. The yellow hue also affected the right half, presenting as irregular obscure patches mainly located near the margin.

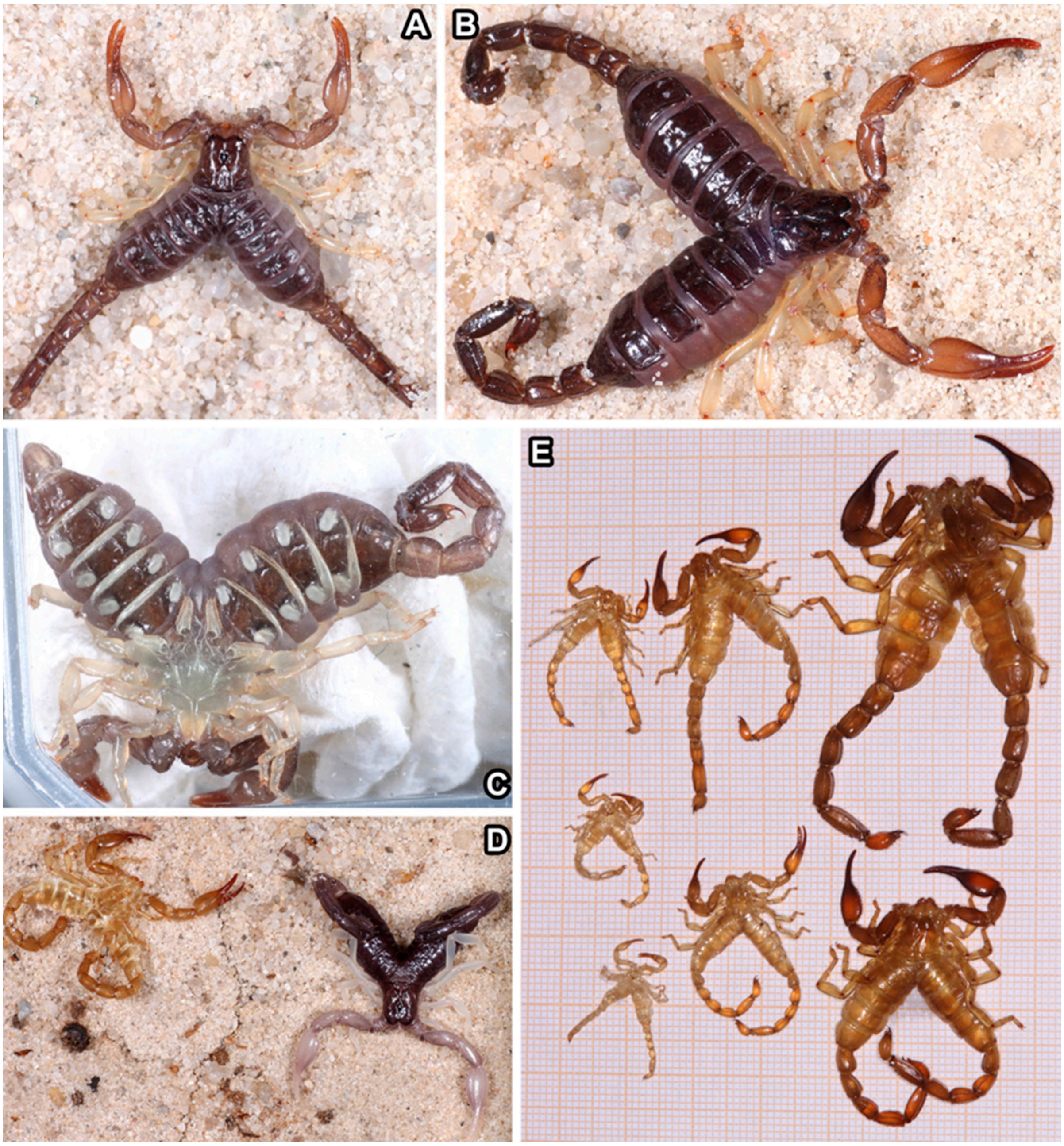

Figure 11. *Nebo whitei* Vachon, 1980, showing duplication starting from the first tergite. (**A**–**D**) Habitus in vivo at different developmental stages. (**E**) Exuviae from the second to eighth instars, in dorsal view. Photos by MS.

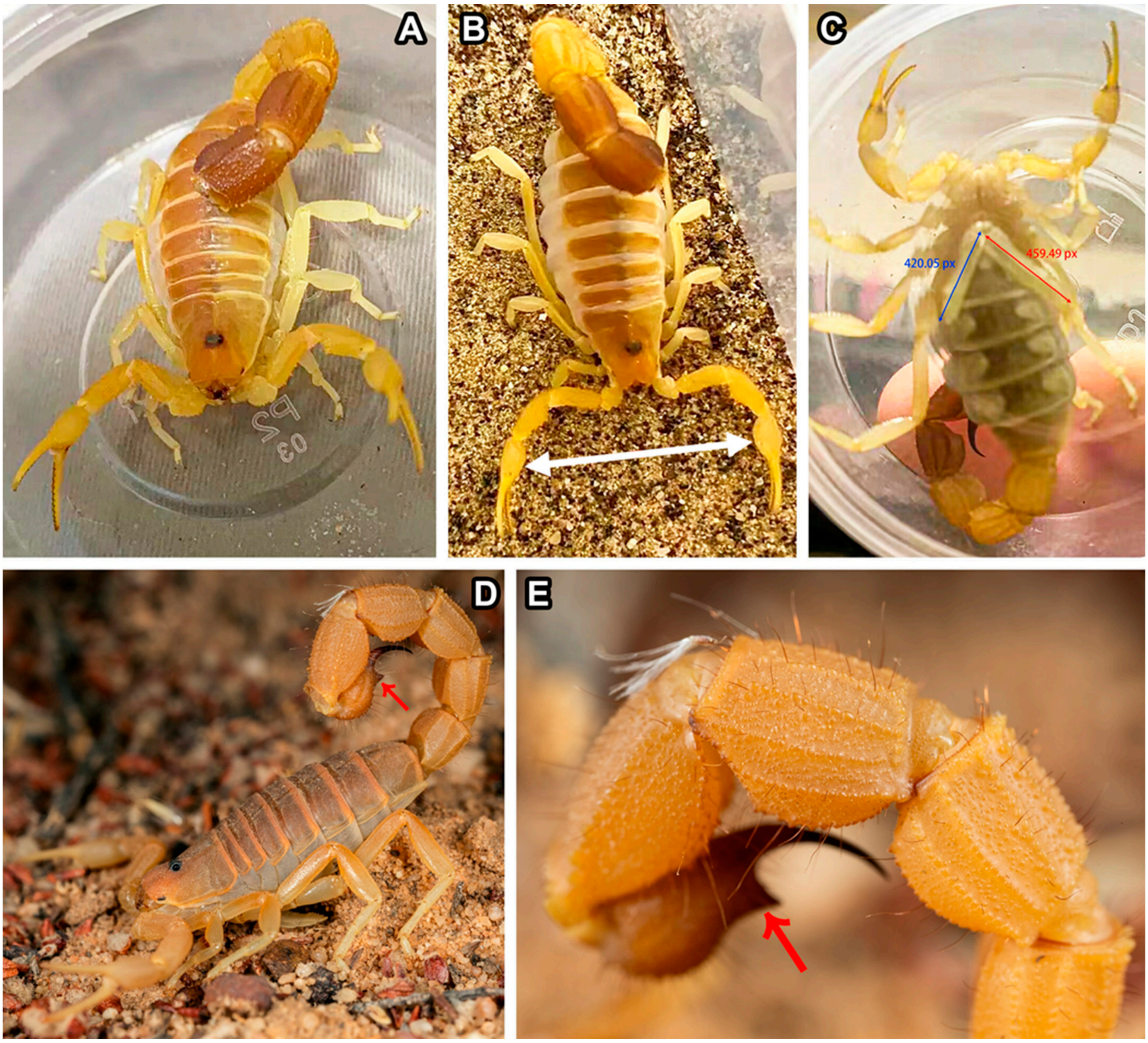

Figure 12. *Parabuthus capensis* (Ehrenberg, 1831), two anomalous specimens. (**A**–**C**) Captive intersex adult demonstrating external gynandromorphism on pedipalp chelae and pectines (with pectine length measured in pixels denoting length asymmetry), as well as chromatic anomaly on prosoma and mesosoma ((**A**–**C**) photos by and courtesy of Yizun Wang). (**D**,**E**) Wild juvenile (or subadult) from West Coast (Western Cape, South Africa) showing pronounced subaculear tubercle ((**D**,**E**) photos by and courtesy of David Taylor, https://www.inaturalist.org/observations/196347236 (accessed on 15 October 2024); CC-BY-NC; http://creativecommons.org/licenses/by-nc/4.0/ (accessed on 15 October 2024). Arrows point to anomalies.

Intersexuality in this specimen was recognised by two sexually dimorphic characters, namely the pedipalp manus and pectines. With reference to Prendini [42] (Figures 54, 62, 64, 66 and 68), *P. capensis*, like many other *Parabuthus* species, exhibits sexual dimorphism in the relative girth of the pedipalp manus and relative length of the pectines. Males tend to have more robust manus and longer pectines compared to females. The specimen in question exhibited morphometric inequality between its left and right manus (and pectines). The left manus was slightly more robust than its right counterpart, thus more akin to a male phenotype. Likewise, the left pectine was longer than its right counterpart. Apparently, the male traits were manifested on the left half of this specimen. Normally, most adult females of *Parabuthus* possess a dilated basal lamellae on each pectine. This structure is, however, indiscernible on the right pectine of this specimen due to resolution constraints.

The second case depicts an unusual protuberance on the telson of an immature female *P. capensis* (Figure 12D,E). The specimen was observed by David Taylor in West Coast (Western Cape, South Africa), near Kliphuis (32°28′12.0″ S 19°13′20.5″ E; iNaturalist record 196347236), and was not collected. The pronounced, triangular process on the ventral surface of the telson of this specimen reminded us of a specialised structure usually termed as the "subaculear tubercle" (SAT). The SAT is present normally in a number of scorpion lineages and varies in shape, most frequently discovered in small, phytophilous buthids (e.g., species from the "*Ananteris*-*Isometrus*" group and "*Centruroides*-*Tityus*" group), as well as the diplocentrids of Iurida, but is absent in buthids from the Palearctic realm. The close phylogenetic relationships amongst genera *Grosphus* Simon, 1880, *Parabuthus* Pocock, 1890; *Teruelius* Lowe & Kovařík, 2019; and *Uroplectes* Peters, 1861 [43] (Figures S1 and S3–S5) prompted us to interpret the observed anomaly from a homologous perspective. In addition, the genus *Parabuthus* is grouped within a clade ("*Charmus*-*Uroplectes*" group) more closely related to a few lineages where the SAT is relatively common, diverging from the Palearctic buthids ("*Buthus*" group, or more informally, Buthidae sensu stricto).

According to Lowe and Kovařík [27] (Figures 181–195), the SAT is absent in all 10 *Teruelius* species they illustrated; on the other hand, three out of five depicted *Grosphus* showed a prominent protuberance at the distal end of the ventromedian axis of the vesicle. Similarly, the SAT is observed in a few (but not all) *Uroplectes* species, such as *U. flavovirids* (Peters, 1861); *U. formosus* (Pocock, 1890); *U. insignis* Pocock, 1890; *U. lineatus* (C. L. Koch, 1844); *U. marlothi* (Purcell, 1901); *U. olivaceus* (Pocock, 1896); and *U. triangulifer* (Thorell, 1876). Indeed, a small knob at the same location as the SAT can be observed in a variety of buthid taxa, even including the Palearctic lineages. Those knobs are typically obsolete and indistinguishable from other small granules on the ventral surface of the vesicle, except for their homologous location relative to the SAT sensu stricto. The SAT is often subjectively identified and ambiguously defined as an "obvious" (usually either lobiform or spiniform) process located on the ventrodistal surface of the vesicle along its medial axis, beneath the aculeus. The authentic biomechanical function of this structure remains unclear, necessitating future ethological studies conducted under laboratory conditions encompassing a broad range of taxa. The observed anomaly may indicate the genetic potential for a granule located at the same position to develop into an SAT. However, more morphological analyses need to be conducted on this structure to show that *Grosphus* and *Uroplectes* SATs share many fine structural details with the anomaly in question.

Conversely, when considering the darkness of the anomalous protuberance, which resembles the basal colour of a normal aculeus (and noting that known SATs in *Grosphus* and *Uroplectes* match their telson colour), this case might be interpreted as aculear duplication. Strict aculear duplication (i.e., discarding metasomal duplication), or presumably so (i.e., additional structures resembling an aculeus), is not a rare teratology observed in scorpions and has hitherto been documented in *Heterometrus longimanus* (Herbst, 1800) [44]; *Androctonus australis* (Linnaeus, 1758) [45,46]; *Leiurus hebraeus* Lowe et al., 2014 [47]; *Isometrus maculatus* (DeGeer, 1778) [4]; *Heteroctenus junceus* (Herbst, 1800) [48]; *Tityus serrulatus* Lutz & Mello, 1922 [49,50]; *Centruroides griseus* (C. L. Koch, 1844) [8]; *Opisthacanthus elatus* (Gervais, 1843) [51]; *Parabuthus liosoma* (Ehrenberg, 1828) [52]; and *Androctonus amoreuxi* (Audouin, 1826) [53], according to Sherwood and Armas [19] (Table 1). Additionally, Salabi et al. [54] reported a case of triplication in an adult male of *Hottentotta zagroensis* Kovařík, 1977.

The report of aculear duplication in *P. liosoma* offers a comparable reference for our observation in *P. capensis*. The secondary aculeus of the anomalous *P. liosoma* was well-developed, slightly shorter and less robust than the normal aculeus, yet demonstrating its capability of venom ejection. It also exhibited a darkened base, as observed in the anomalous *P. capensis*. The short profile of the protuberance of the specimen of *P. capensis* prevented us from definitively classifying it as a secondary aculeus. Another likelihood is that SATs might represent precursors to secondary aculei or may share genetic traits that predispose the development of secondary aculei from SATs. Nevertheless, current genetic knowledge on both aculeus mutations and SATs is lacking, and these are presented merely as hypotheses.

3.13. *Scorpiops aff. vachoni (Qi, Zhu & Lourenço, 2005) (Scorpiopidae)*

Remarks. The author VT obtained a an adult female *Scorpiops* with the only known locality data of "Yunan, China", now preserved in ethanol, with proliferated telotarsi on its left leg II tibia (Figure 13A–F). Given its morphology, it is most likely allied to a morphospecies already known from the province of Yunnan (VT pers. obs.). The specimen was tentatively identified as *S*. aff. *vachoni* based on the shape of the chelae, basal lobe of the moveable finger, and following morphometrics, according to Tang [55] (Table 2): PTC 7/7, P-Vt 10/11, ID 7/7, OD 13/13, MD 92/97, and IAD 55/55.

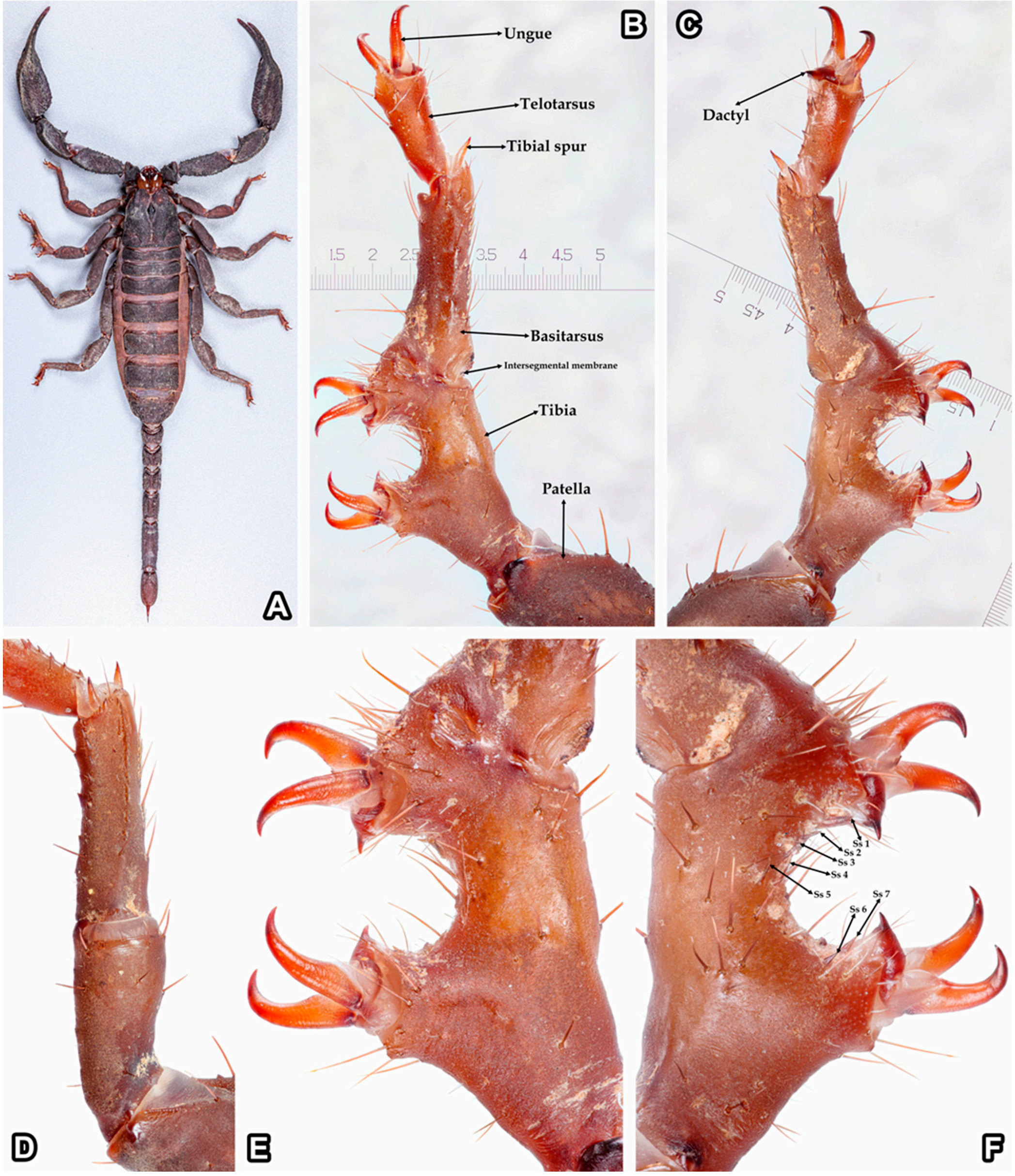

Figure 13. *Scorpiops* aff. *vachoni* (Qi, Zhu & Lourenço, 2005), anomalous adult female; DIV = 50 µm. (**A**) Overall post-mortem habitus. (**B**,**E**) Anomalous (left) leg II in prolateral view. (**C**,**F**) Anomalous (left) leg II in retrolateral view. (**D**) Normal leg (right) II (basitarsus and tibia) in retrolateral view. Abbreviation: Ss = spinule-like structure. Photos by VT.

The observed anomaly on its left leg II is primarily confined to the tibia, manifested as two opposing, distally developed telotarsi (henceforth referred to as "apotele") arrayed along the dorsal margin (Figure 13B,C). We define the apotele close to the patella–tibial joint as the proximal apotele, and the one close to the tibia–basitarsal joint as the distal apotele. The proliferation of apoteles caused deformation on the dorsal portion of the tibia, resulting in a shallow depression (which may appear deeper due to the elevated apoteles flanking this margin). The distal apotele also affected the tibia–basitarsal joint, rendering a conspicuous bulge at this junction. The deformity further interrupted the formation of segmental division at the same location and consequently that of its associated intersegmental membrane. The tibia and basitarsus were nearly fused, leaving only some traces of sutures. However, a small remnant of the intersegmental membrane was observed on the ventral margin at this joint. Both apoteles were equipped with a pair of fully developed ungues and one dactyl, tilting slightly towards each other at a certain angle. Seven spinule-like structures were identified along the concave surface between the two apoteles, of which two were closer to the proximal apotele and two arranged transversely (Figure 13F). The vicinity of the distal apotele was notably more setose, and additional setae were also present on the retrolateral surface compared to the normal right leg II (Figure 13D). A similar case was reported in *Centruroides edwardsii* (Gervais, 1843) by Armas [56] (misidentified as *C. margaritatus* (Gervais, 1841)), where two additional pairs of apoteles were present at the basi–telotarsal joint, pointing in opposite directions [56] (Figure 1).

Deformities associated with telotarsi and tarsal ungues are relatively common with respect to other types of anomalies (e.g., [19] (Figures 1, 3, 10–11 and 14–19); [20] (Figure 2); [57] (Figure 127)), constituting 50 out of 242 cases (~21%) as summarised in Sherwood and Armas [19] (Table 1). However, those previously reported cases mostly likely represented structural regenerations from postnatal injuries [58,59] rather than congenital teratology due to genetic mutations. The ability of scorpions to regenerate is relatively poor compared to that of other arachnids, such as spiders, which can recover the entire lost leg ([60], DS pers. obs.). In contrast, regeneration associated with locomotory appendages seems to be mainly restricted to that of the most vital anatomical parts in scorpions, in an energetically abstemious manner. This is often manifested as the regeneration of tarsal ungues, dactyls, and surrounding setae at the truncated apex, although the extent may vary amongst individuals. However, the anomaly reported in this adult female *Scorpiops* does not appear to be a case of regeneration.

Firstly, if the proximal apotele was a result of severance near the patella–tibial joint, the regenerated tarsus would align with the remaining fraction tibial segment along the same proximo-distal axis. Similarly, if the distal apotele was regenerated for the same reason, then the more distal extremities (i.e., basi- and telotarsi) should be absent from this junction. Additionally, for these two anomalous apoteles to be a more plausible result of regeneration due to injury, one would expect there to be two sites along the associated dorsal margin where they had been partially pared (i.e., the basal cross-sections of the two apoteles). However, scorpions have never been known to regenerate pared surfaces, and personal observations suggest that those injuries would be replaced by dark scabs if they eschewed degeneration due to bacterial or fungal infection. In an unlikely event, the two pared surfaces of this specimen (if it is a case of postnatal injury) might be replaced by those apoteles as a consequence of mutations in genes controlling tissue and/or cuticle recovery. A more probable explanation is that those anomalies were prenatal, possibly corresponding to a phenomenon known as polydactyly. However, polydactyly typically expresses in proximity to normal digits, whereas the specimen's proliferated apoteles are distantly located from the segment bearing this structure. On the other hand, the case reported by Armas [56] seemed to be more accordant with the typical syndrome of polydactyly. Thus, the exact nature of the present anomaly remains unresolved, though it is likely attributable to a genetic mutation affecting the location of tarsal development.

Further records of morphological anomalies with this genus associated with trichobothria, pectinal teeth, and pedipalp moveable finger denticles have been extensively discussed and illustrated in Tang [61] (Refs. 31, 32, 34, 43, Figures 54, 56, 80, 83, 85, 103, 105, 119, 121, 149, 181, 182, 217 and 268), Tang [62] (Refs. 12, 13, 16, 19, Figure 84), and Tang [55] (Refs. 6, 18, 26, 28, Figures 72 and 73).

3.14. Tetratrichobothrius flavicaudis (De Geer, 1778) (Euscorpiidae)

Remarks. We report three new cases of deformities in *T. flavicaudis*. In all cases, accurate species-level identification was achieved by the examination of the trichobothriotaxy of the chela manus of the pedipalp.

An adult female specimen with a mesosomal teratology was encountered by author VG in Italy (Lazio, Rome, Carpineto romano; 41°34′51.8″ N 13°07′51.4″ E; 4/V/2024; on a rock in a mixed forest of *Quercus ilex* surrounded by forests of *Quercus cerris*, *Carpinus betulus*, and conifers). The specimen presents a longitudinal division of tergites II, III, and IV, converging on a depression and connected by membrane (Figure 14A–C). All affected tergites are strongly curved and show a similar disposition to the two *Lychas* spp. specimens described above, only differing in the tergites affected and the size of the depression. Dissection of the mesosoma from the ventral side of the specimen revealed that the internal anatomy was not visibly affected by the split of the tergites. Notably, the heart was unaffected despite its proximity to the tergal division; as such, it can be tentatively inferred that the ectoderm was the only primary germ layer responsible for this teratology during embryonic development.

The second case is a likely adult female with a deformed and non-functional telson, unlikely teratological in nature and more likely related to and old injury or complication during ecdysis. The vesicle appears twisted and partially deflated, and the tip of the aculeus is broken off (Figure 14D,E). This specimen was collected in France by the author JT (full data: Occitanie, Hérault, Montpellier; 43°37′45.7″ N 3°53′33.9″ E; 3/VI/2024; under rocks in an urban park) and remains alive (time of writing: November 2024).

Finally, a juvenile specimen with metasomal duplication starting from mesosomal segment VI was collected in France in 1987 (full data: Provence-Alpes-Côte d’Azur, Alpes-de-Haute-Provence, Dignes-les-Bains) and later presented to author JT (Figure 14F). This is the second known record of metasomal duplication in this species and the second published record of this teratology from European scorpions [63]. In this specimen, both metasomas are anatomically complete but only one mesosoma VII is complete, the other appearing to be fused to mesosoma VI.

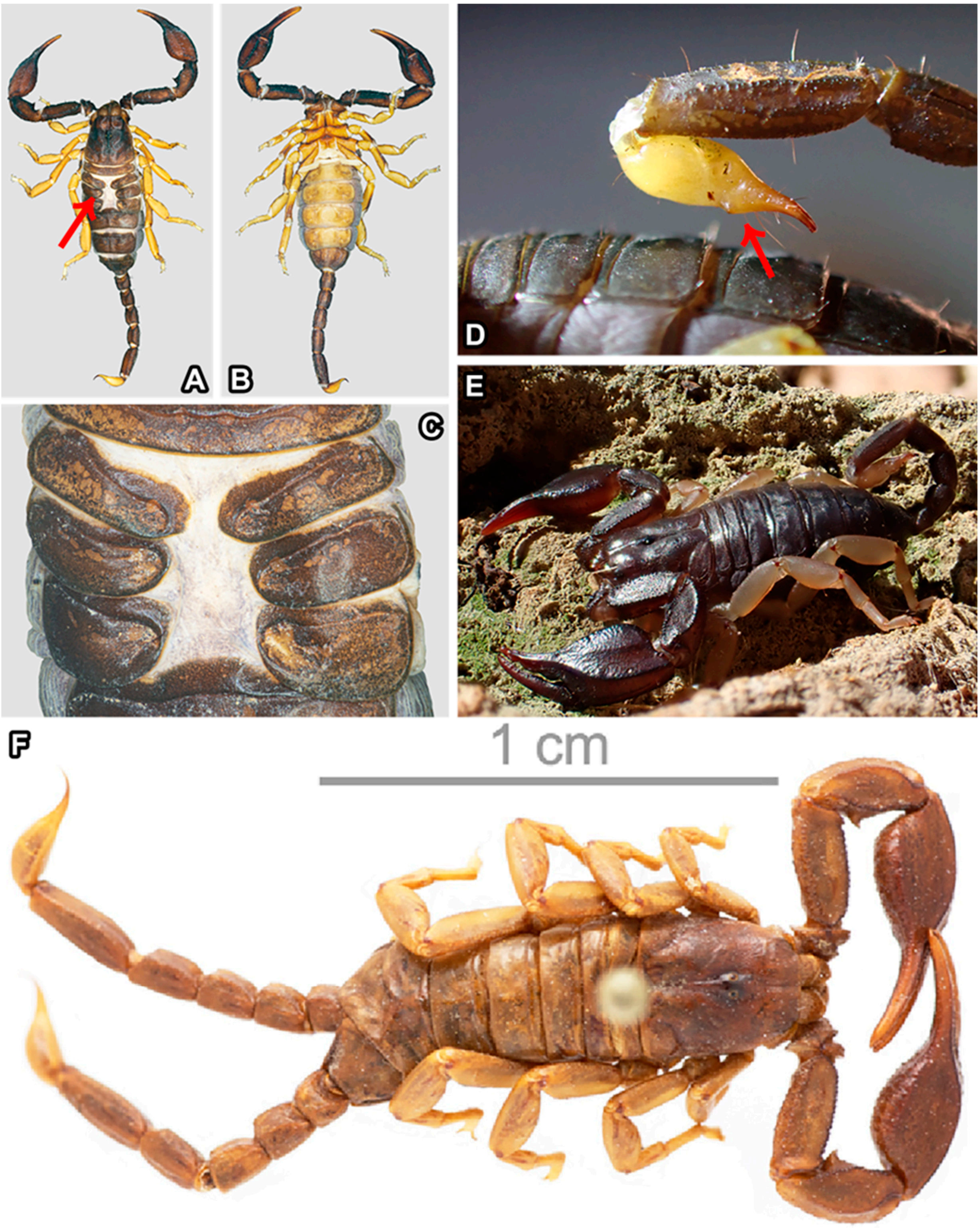

Figure 14. *Tetratrichobothrius flavicaudis* (DeGeer, 1778), anomalous specimens. (**A**–**C**) Adult female showing wide division of the mesosomal tergites II–IV. (**A**) Post-mortem habitus, dorsal side. (**B**) Post-mortem habitus, ventral side showing no abnormalities. (**C**) Close-up view of the affected area in dorsal view. (**D**,**E**) Probable adult female showing a deformed telson. (**D**) Close-up view of the anomalous vesicle and aculeus in lateral view. (**E**) Habitus of the same specimen. (**F**) Habitus of the preserved juvenile specimen of *T. flavicaudis* in dorsal view (photographs by and courtesy of Benjamin Bentameur). Photos (**A**–**E**) by JT and LL. Arrows point to anomalies.

4. Discussion

This work significantly expands knowledge of scorpion teratology, abnormalities, and other atypical presentations in habitus or morphology. Building on the work of Sherwood and Armas [19] and an online summary of internet reports by Tang [64], we contribute a number of newly reported phenomena in scorpions, such as the first known partial duplication of the cephalothorax, presence of three chelae, and new knowledge on the lifecycle of scorpions with reduced or no pigment in the exoskeleton. In total, 18 new reports of teratology overall are presented. No true correlation is apparent in comparing the anomalies and other morphological processes reported herein against the phylogenetic identity of the respective taxa.

A better understanding of teratology and healing processes from injuries contributes to knowledge on overall biological processes such as ontogeny, sexual dimorphism, and comparative anatomy. There is significant opportunity in the future for further advancement of our knowledge of teratology and atypical colouration in scorpions. The reporting of new cases and advanced analysis of prior cases using new methods such as scanning electron microscopy and/or molecular analysis could reveal new insights into physical processes and could reveal further morphological evidence not possible with the contemporary methods used in the present work. Nonetheless, is hoped that the present contribution, in conjunction with the large amount of data already collated previously by Sherwood and Armas [19], will form part of the tapestry which enables future work.

Author Contributions: Conceptualization, D.S.; methodology, D.S., V.T. and J.T.; investigation, D.S., V.T., J.T., L.L., S.C., M.S., J.K. and V.G.; writing—original draft preparation, D.S.; writing—review and editing, D.S., V.T., J.T., L.L., S.C., M.S., J.K. and V.G.; project administration, D.S. All authors have read and agreed to the published version of the manuscript.

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