OSMIA
ISSN 2727-3806

Revue d'Hyménoptérologie
Journal of Hymenopterology
https://doi.org/10.47446/OSMIA

Volume 13
2025

ARTICLE

A new case of gynandromorphism in the parasitic bee *Nomada lathburiana* (Hymenoptera: Apoidea: Apidae)

Frédéric Carion[1] • William Fiordaliso[2] • Clément Tourbez[3] • Paolo Rosa[4] • Denis Michez[5] • Guillaume Ghisbain[6]

Carion, F., W. Fiordaliso, C. Tourbez, P. Rosa, D. Michez & G. Ghisbain (2025). A new case of gynandromorphism in the parasitic bee *Nomada lathburiana* (Hymenoptera: Apoidea, Apidae). *Osmia*, **13**: 61–68. https://doi.org/10.47446/OSMIA13.3

Abstract
Gynandromorphy is a case of teratological aberration in which a specimen displays both male and female morphological characters. Gynandromorphs can constitute a powerful source of information for pairing sexes and studying the developmental mechanisms underlying sexually dimorphic traits. In this paper, a second case of gynandromorphy is unveiled in a specimen of *Nomada lathburiana* found in Tournai (Belgium). The studied specimen, classified as a mosaic gynandromorph, displays a largely asymmetric mix of male and female features only on the head. Further research in entomological collections should reveal other cases of teratological aberrations like the one reported here. Such cases offer valuable insights into the broader understanding of gynandromorphy.

Keywords | Bee • development • gynander • nomad bee • ontology • teratology

Un nouveau cas de gynandromorphisme chez l'abeille parasite *Nomada lathburiana* (Hymenoptera : Apoidea : Apidae)

Résumé
La gynandromorphie est un cas d'aberration tératologique dans lequel un spécimen présente à la fois des caractères morphologiques mâles et femelles. Les gynandromorphes peuvent constituer une source d'information intéressante pour étudier l'association des sexes et les mécanismes de développement qui sous-tendent les caractères sexuellement dimorphiques. Dans cet article, un deuxième cas de gynandromorphie est découvert sur un spécimen de *Nomada lathburiana* trouvé à Tournai (Belgique). Le spécimen étudié, classé comme un gynandromorphe « mosaïque », présente uniquement sur la tête un mélange largement asymétrique de traits mâles et femelles. Des recherches plus poussées dans les collections entomologiques devraient révéler d'autres cas d'aberrations tératologiques comme celui rapporté ici. Ces cas offrent des indications précieuses pour une meilleure compréhension de la gynandromorphie.

Mots-clefs | Abeille • développement • gynandromorphe • abeille nomade • ontologie • tératologie

Reçu • Received | 30 August 2024 || **Accepté • Accepted** | 27 August 2025 || **Publié (en ligne) • Published (online)** | 30 August 2025
Reviewers | E. Gigandet • G. Nève || https://zoobank.org/84471A21-FE06-4004-A31E-C0CF44BABE42

INTRODUCTION

Teratology is the discipline that studies the malformations and developmental defects in living beings (Lombardo & Marletta, 2022; Calado *et al.*, 2024). It comes from the Greek word "*teratos*" meaning "monster" (Calado *et al.*,

[1] [FC] Laboratory of Zoology, Research Institute for Biosciences, University of Mons, Place du parc 20, B – 7000 Mons, Belgium • frederic.carion@student.umons.ac.be • https://web.umons.ac.be/zool/ • https://orcid.org/0009-0001-4944-4353 • ZooBank https://zoobank.org/5FD976B2-92DE-439D-A374-C5A055F1ADC3
[2] [WF] Laboratory of Zoology, Research Institute for Biosciences, University of Mons, Place du parc 20, B – 7000 Mons, Belgium • william.fiordaliso@umons.ac.be • https://web.umons.ac.be/zool/ • https://orcid.org/0000-0002-9667-6800 • ZooBank https://zoobank.org/18ED1A31-C3BF-4588-9844-3C2B139596E5
[3] [CT] Laboratory of Zoology, Research Institute for Biosciences, University of Mons, Place du parc 20, B – 7000 Mons, Belgium • clement.tourbez@umons.ac.be • https://web.umons.ac.be/zool/ • https://orcid.org/0000-0003-1783-5824 • ZooBank https://zoobank.org/7A28EE99-8CE7-448D-8EC8-B7AF6917363D
[4] [PR] Laboratory of Zoology, Research Institute for Biosciences, University of Mons, Place du parc 20, B – 7000 Mons, Belgium • paolo.rosa@umons.ac.be • https://web.umons.ac.be/zool/ • https://orcid.org/0000-0003-2919-5297 • ZooBank https://zoobank.org/F1E8DF8A-6105-4AC8-96F9-31EDA674D320
[5] [DM] Laboratory of Zoology, Research Institute for Biosciences, University of Mons, Place du parc 20, B – 7000 Mons, Belgium • denis.michez@umons.ac.be • https://web.umons.ac.be/zool/ • https://orcid.org/0000-0001-8880-1838 • ZooBank https://zoobank.org/8B04585A-FE00-4D9A-AFD6-1BD2A1584CFA
[6] [GG] Laboratory of Zoology, Research Institute for Biosciences, University of Mons, Place du parc 20, B – 7000 Mons, Belgium • guillaume.ghisbain@umons.ac.be • https://web.umons.ac.be/zool/ • https://orcid.org/0000-0003-2032-8081 • ZooBank https://zoobank.org/FD9CD87B-EAAB-4037-BFDE-58AE0E7349B7

2024). Among the teratological aberrations found in animals is gynandromorphy, in which individuals display both male and female morphological characteristics (MICHEZ *et al.*, 2009; CAMARGO & GONÇALVES, 2013; GIL, 2015; BABA *et al.*, 2016; LE FÉON *et al.*, 2016; ALVAREZ *et al.*, 2019; ROGERS *et al.*, 2021).

Arthropods are generally sexually dimorphic, as they differentiate either into complete males or into complete females. Amongst Arthropods, gynandromorphy mainly comes from an abnormal chromosomic distribution and occurs at a low frequency under natural conditions (NARITA *et al.*, 2010; SUZUKI *et al.*, 2014). This type of teratology results from dysfunctions in the sex-determining system and can be explained by various mechanisms, including a loss or damage of a sex chromosome, the generation of a binucleate egg or an infection by parasites (*e.g.*, Bacteria of the genus *Wolbachia*) (NARITA *et al.*, 2010).

Three categories of gynandromorphs are recognised, depending on the distribution of the male and female features on the body: mosaic gynandromorphs, bilateral gynandromorphs and transversal gynandromorphs (MICHEZ *et al.*, 2009). Mosaic gynandromorphs are defined by the development of disordered patches of traits from the other sex on the body. Bilateral gynandromorphs are defined by a difference of morphological features on each side of the sagittal plan, leading to a 'half male and half female' specimen. Transversal gynandromorphs are defined by male and female morphological features exclusively distributed on each side of a transversal plan across the body (MICHEZ *et al.*, 2009; BARRETT, 2021).

Amongst the Arthropods in which gynandromorphy is well studied are bees (Hymenoptera: Anthophila), a widespread group of vital pollinators classified in seven families and more than 20,000 described species worldwide (MICHENER, 2007; MICHEZ *et al.*, 2019). Gynandromorphs are reported as relatively common in this group, with cases of gynandromorphy documented in six of the seven bee families (BARRETT, 2021). In total, about 30 genera include reported cases of gynandromorphy (HINOJOSA-DÍAZ *et al.*, 2012; LUCIA *et al.*, 2015). After the family Megachilidae, Apidae is the second bee family with the highest number of reported gynandromorphs (GIANGARELLI & SOFIA, 2011; LUCIA *et al.*, 2012; LE FÉON *et al.*, 2016). Within this family, the parasitic bee genus *Nomada*, containing around 800 accepted species worldwide (ASCHER & PICKERING, 2024), includes only a few taxa with reported gynandromorphs, each taxon having only one case of gynandromorphy, namely:

- *Nomada flava* PANZER, 1798 which is widely distributed in Europe (SMIT, 2018); this case was studied by LE FÉON *et al.* (2016).
- *Nomada fucata* PANZER, 1798 which is widely distributed in Europe, North Africa, the Middle East and Asia (SMIT, 2018); this case was studied by SCHENCK (1871).
- *Nomada lathburiana* (KIRBY, 1802) which is widely distributed in Europe, but which also occurs in North Africa (Tunisia), the Middle East (Turkey) and Asia (Georgia, Armenia, Tajikistan, Kazakhstan, Eastern Siberia, North China) (SMIT, 2018); this case was also studied by LE FÉON *et al.* (2016).
- *Nomada sanguinea* SMITH, 1854 (under the name *Nomada laevilabris* SCHMIEDECKNECHT, 1882) which is distributed in Western (Southeast of France) and Southern Europe but also North Africa (Algeria, Morocco, Tunisia) (SMIT, 2018); this case was studied by PÉREZ-IÑIGO MORA (1982).
- *Nomada* sp., an unidentified specimen found in Japan and studied by TSUNEKI (1975).

The present article adds a second case of gynandromorphy in *N. lathburiana* (KIRBY, 1802).

MATERIAL AND METHODS

The specimen of *Nomada lathburiana* was collected by team members of the Laboratory of Zoology at the University of Mons, Belgium (UMons). It was found in the quarry "Carrière de Gaurain" in Tournai (50.6089 N; 3.4939 E), on April 5th, 2024. The specimen was collected by net close to nests of *Andrena vaga* PANZER, 1799 which is the host of *N. lathburiana* (BISCHOFF, 2003; SMIT, 2018).

In order to assess the gynandromorphy of the specimen studied, it was first visually analysed and then compared with specimens hosted in the collection of the Laboratory of Zoology (UMons) but also with the diagnostic morphological characters provided by SMIT (2018).

Images of the specimens and features were taken with an Olympus OMD E-M1 Mark II photo camera with the Olympus Zuiko 60 mm objective and a Mitutoyo plan achromatic lens LWD 5x. Images were stacked with the Helicon© software and then enhanced with Adobe Photoshop© CS6, by cleaning the dust on the specimens and adjusting the white balance.

The gynandromorph specimen is hosted in the collection of the Laboratory of Zoology at UMons.

RESULTS

A visual analysis of the external morphology of the studied specimen reveals that only the head exhibits both male and female characteristics (table I, figures 1–3), while the mesosoma and metasoma are distinctly feminine (figures 1–2).

Table 1. Description of male and female traits on the head of *N. lathburiana* studied here.

Structures examined	Male traits	Female traits
Marking of the face	Supraclypeal area, clypeus, labrum, left oculomalar area and both paraocular areas mainly yellow.	Clypeus (partly), labrum (partly) and right oculomalar area (partly) with red-orange spots.
Inner margins of the compound eyes	Left inner margin of the compound eye mainly yellow.	Right inner margin of the compound eye mainly red/orange.
Mandibles	Mandibles basally with yellow spots.	Both mandibles mainly red, except basally.
Scape	Scape of both antennae yellow on the front side and black on the dorsal side.	No female trait.
Antennae	Left antenna with 13 articles, ventrally nodose from article 4 to 13.	Right antenna with 12 cylindrical articles.
Compound eyes	Left compound eye comparatively greener and smaller.	Right compound eye comparatively redder and larger.
Hairs of the face	Scape, supraclypeal area, clypeus, labrum and vertex with silver hairs.	Clypeus (partly), labrum (partly) and vertex (partly) with patches of red-orange hairs.
Hairs of the frons and genae	Middle and left side of the frons with silver hairs.	Both genae and right side of the frons with red-orange hairs.
Marking of the genae	Left gena, on the outer margin of the compound eye, except near the vertex, mainly yellow. Right gena without male traits.	Left gena, on the outer margin of the compound eye, near the vertex, with small red spots. Right gena, on the outer margin of the compound eye, near the vertex, entirely red.

DISCUSSION

The studied specimen of *Nomada lathburiana* displays a mix of largely asymmetric male and female traits on the head and can therefore be regarded as a mosaic gynandromorph. The previous gynandromorph of *N. lathburiana* was also classified as such (Le Féon *et al.*, 2016). This class was considered the most common among the three aforementioned categories by Wcislo *et al.* (2004) but later considered as the second most common, after the transverse class, in the review of Michez *et al.* (2009).

A morphological study of the specimen treated in this paper reveals a slight difference of size between the two compound eyes. The female-like compound eye is larger than the male-like one, a difference which was also observed in the other known gynandromorph of this species (Le Féon *et al.*, 2016). Well-developed compound eyes in insects are generally associated with a wide field of vision and are usually found in searching and hunting species (Chapman *et al.*, 2013). Non-teratological specimens also have slightly larger compound eyes in females, which is expected as females are the ones that search for nests to lay their eggs.

The two antennae of the gynandromorph specimen exhibit a difference in the number of antennal articles, with the left antenna having 13 articles. This discrepancy was also observed in the previous gynandromorph specimen of the same species (Le Féon *et al.*, 2016). Typically, bees have 12 articles in females and 13 in males, including *Nomada* (Michener, 2007; Smit, 2018; Michez *et al.*, 2019). This is the only symmetrical difference present in the gynandromorph examined in this article.

The shape of the antennal articles also differs between the two antennae. The male-like antenna features nodose articles, with rounded tubercles on articles 4 to 6 and sharp tubercles on articles 7 to 13, which is a diagnostic character of male of *N. lathburiana* (Smit, 2018). This difference in shape is likely due to distinct evolutionary patterns between male and female antennae, resulting in sexual dimorphism. In males, these tubercles are associated with glands, probably involved in the transfer of pheromones from male to female during the courtship and mating behaviour (Schindler *et al.*, 2018).

Although both recorded gynandromorphs of *N. lathburiana* are considered in the same class of gynandromorphy

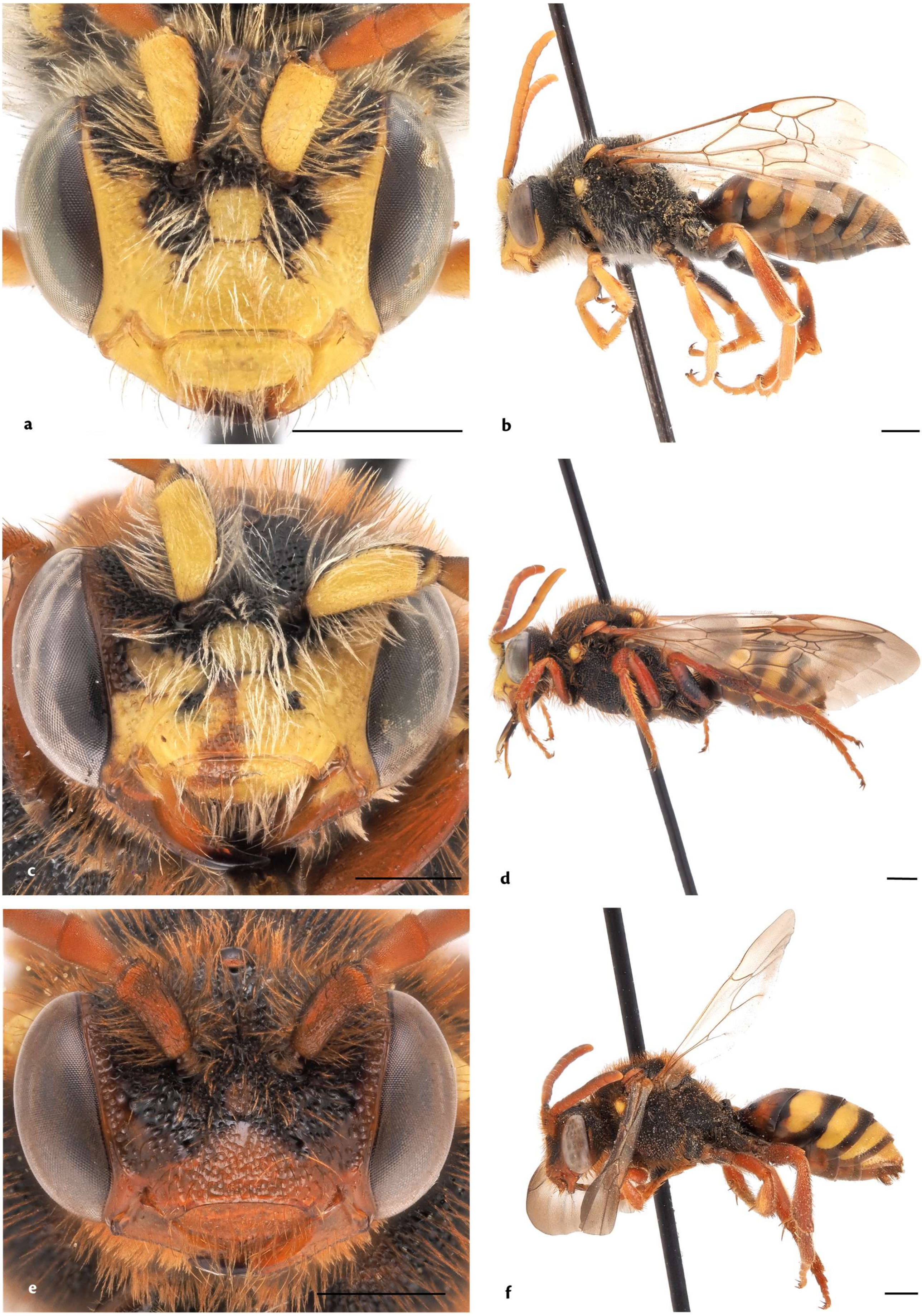

Figure 1. Morphological comparison of the gynandromorph specimen of *Nomada lathburiana* collected in Tournai (Belgium) with non-teratological (normal) specimens collected in Belgium. The scales represent one millimetre. **a.** Front view of the head of a normal male specimen. **b.** Lateral view of a normal male specimen. **c.** Front view of the head of the gynandromorph specimen. **d.** Lateral view of the gynandromorph specimen. **e.** Front view of the head of a normal female specimen. **f.** Lateral view of a normal female specimen.

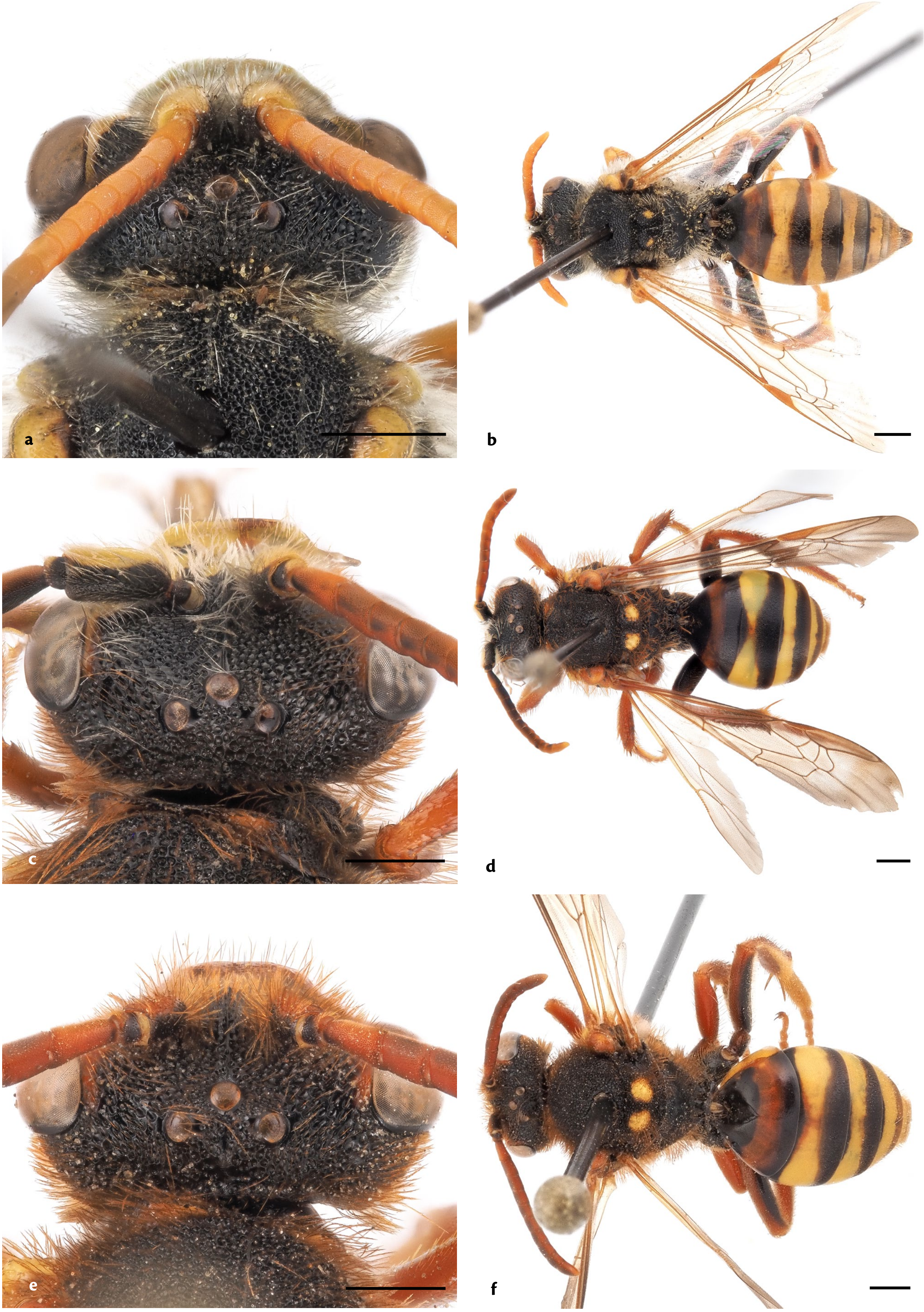

Figure 2. Morphological comparison of the gynandromorph specimen of *Nomada lathburiana* with non-teratological (normal) specimens. The scales represent one millimetre. **a.** Dorsal view of the head of a normal male specimen. **b.** Dorsal view of a normal male specimen. **c.** Dorsal view of the head of the gynandromorph specimen. **d.** Dorsal view of the gynandromorph specimen. **e.** Dorsal view of the head of a normal female specimen. **f.** Dorsal view of a normal female specimen.

Figure 3. Antennae of the gynandromorph specimen of *Nomada lathburiana*. The scales represent one millimetre. **a.** Frontal view of the right antenna showing 12 articles. **b.** Oblique view of the left antenna showing 13 articles including ventrally nodose antennal articles.

(*i.e.*, the mosaic class), differences exist between these specimens. The previously known specimen displays more male-like morphological features with the terminal tergites typically male-like (LE FÉON *et al.*, 2016). LE FÉON *et al.* (2016) studied a specimen with characters almost distributed on each side of the sagittal plan, which recalls the bilateral class of gynandromorphy. The specimen studied in this article only presents a mosaic of characteristics on the head, which is reminiscent of transversal gynandromorphs. The study of these two specimens illustrates how different ontologies can lead to distinct gynandromorph phenotypes, even within a single species.

The origins of the gynandromorphy of the specimen studied in this article is unknown. However, quarries are environments polluted by heavy metals (OGBONNA *et al.*, 2011; LAGO-VILA *et al.*, 2016). Some of these can show mutagenic and teratogenic effects (GERBER *et al.*, 1980; LEONARD & LAUWERYS, 1980; DEGRAEVE, 1981; LÉONARD *et al.*, 1984; WEBSTER, 1990; BOEING *et al.*, 2024), and can accumulate in pollen and nectar, the main resources provided by female bees to their offsprings (OGBONNA *et al.*, 2011; BĂRBULESCU *et al.*, 2022; GEKIÈRE *et al.*, 2023). With this in mind, it can be hypothesized that the presence of heavy metals inside the soil and the food could lead to a higher risk of teratogenic aberration such as gynandromorphy. However, the infection by the bacterial genus *Wolbachia* is another possible hypothesis that was presented by NARITA *et al.* (2010). Analysis of the soil of the "Carrière de Gaurain" could give an insight into which hypothesis should be favoured as no such data currently exist.

Descriptions of more gynandromorphs, and teratological aberrations in general, can provide insights into the understanding of the origins of these anomalies and more generally a better understanding of mechanisms of development, regulation of phenotype expression and sex differentiation (WCISLO *et al.*, 2004; MICHEZ *et al.*, 2009; NARITA *et al.*, 2010; LE FÉON *et al.*, 2016). In this context, other aspects than external features of these abnormal specimens, such as genetics and behaviour, would be interesting to study in order to understand the causes of such aberrations and the possible links between the morphological features, the genotype and the behaviour of teratological specimens (ENGEL, 2007; SUZUKI *et al.*, 2014; LE FÉON *et al.*, 2016).

ACKNOWLEDGMENTS

We would like to thank the two collectors of the specimen studied in this article, Alice MARIN and Victoria FRAGAPANE.

REFERENCES

ALVAREZ, L. J., W. P. SILVA, M. LUCIA & A. J. AGUIAR (2019). The first cases of gynandromorphism in oil collecting bees (Hymenoptera, Apidae: Centridini, Tapinotaspidini). *Papéis Avulsos de Zoologia*, **59**: e20195936. https://doi.org/10.11606/1807-0205/2019.59.36

ASCHER, J. S. & J. PICKERING (2024). Bee species guide and world checklist (Hymenoptera: Apoidea: Anthophila). *Discover Life.* http://www.discoverlife.org/mp/20q?guide=Apoidea_species [accessed 03rd August 2024]

BABA, Y. G., T. SUGURO, N. NAYA & T. YAMAUCHI (2016). A gynandromorph of the funnel-web spider *Allagelena opulenta*; (Araneae: Agelenidae). *Acta Arachnologica*, **65**(1): 11–13. https://doi.org/10.2476/asjaa.65.11

BĂRBULESCU, A., L. BARBEȘ & C. Ș. DUMITRIU (2022). Impact of soil pollution on melliferous plants. *Toxics*, **10**(5): 239, 15 pp. https://doi.org/10.3390/toxics10050239

BARRETT, M. (2021). The first case of gynandromorphy in *Centris pallida* (Hymenoptera: Apidae: Centridini). *Journal of Melittology*, **104**: 1–8. https://doi.org/10.17161/jom.i104.13782

BISCHOFF, I. (2003). Population dynamics of the solitary digger bee *Andrena vaga* PANZER (Hymenoptera, Andrenidae) studied using mark-recapture and nest counts. *Population Ecology*, **45**(3): 197–204. https://doi.org/10.1007/s10144-003-0156-6

BOEING, G. A. N. S., M. PROVASE, E. TSUKADA, R. F. SALLA & F. C. ABDALLA (2024). Genotoxic effect of two environmentally safe doses of cadmium on the Hepato-nephrocytic system of *Bombus atratus* forager workers. *Environmental Toxicology and Pharmacology*, **108**: 104450. https://doi.org/10.1016/j.etap.2024.104450

CALADO, A. M., F. SEIXAS & M. D. A. PIRES (2024). Updating an Overview of Teratology, pp. 1–38. *In* FÉLIX, L. (ed.). *Teratogenicity testing.* Humana Press, New York (USA), XVI + 327 pp. https://doi.org/10.1007/978-1-0716-3625-1_1

CAMARGO, M. P. & R. B. GONÇALVES (2013). Register of a gynandromorph of *Euglossa pleosticta* DRESSLER (Hymenoptera, Apidae). *Revista Brasileira de Entomologia*, **57**(4): 424–426. https://doi.org/10.1590/s0085-56262013005000033

CHAPMAN, R. F., S. J. SIMPSON (ed) & A. E. DOUGLAS (ed.) (2013). *The Insects: Structure and Function*. Cambridge University Press, New York (USA), 961 pp.

DEGRAEVE, N. (1981). Carcinogenic, teratogenic and mutagenic effects of cadmium. *Mutation Research/Reviews in Genetic Toxicology*, **86**(1): 115–135. https://doi.org/10.1016/0165-1110(81)90035-x

ENGEL, M. S. (2007). A lateral gynandromorph in the bee genus *Thyreus* and the sting mechanism in the Melectini (Hymenoptera: Apidae). *American Museum Novitates*, **2007**(3553): 1–11. https://doi.org/10.1206/0003-0082(2007)530[1:ALGITB]2.0.CO;2

GEKIÈRE, A., M. VANDERPLANCK & D. MICHEZ (2023). Trace metals with heavy consequences on bees: A comprehensive review. *Science of the Total Environment*, **895**: 165084. https://doi.org/10.1016/j.scitotenv.2023.165084

GERBER, G., A. LÉONARD & P. JACQUET (1980). Toxicity, mutagenicity and teratogenicity of lead. *Mutation Research/Reviews In Genetic Toxicology*, **76**(2): 115–141. https://doi.org/10.1016/0165-1110(80)90006-8

GIANGARELLI, D. C. & S. H. SOFIA (2011). First record of a gynandromorph orchid bee, *Euglossa iopoecila* (Hymenoptera: Apidae: Euglossini). *Annals of the Entomological Society of America*, **104**(2): 229–232. https://doi.org/10.1603/an10104

GIL, J. M., G. MARIN-ESPINOZA, N. PACHECO & R. ZAVALA-MARCANO (2015). Ginandromorfismo bilateral en *Agapornis* sp. (Psitaciformes Psittaculidae). *The Biologist*, **13**(1): 161–163. https://sisbib.unmsm.edu.pe/bvrevistas/biologist/v13_n1/pdf/n3v13n1.pdf [accessed 15 August 2024]

HINOJOSA-DÍAZ, I. A., V. H. GONZALEZ, R. AYALA, J. MÉRIDA, P. SAGOT & M. S. ENGEL (2012). New orchid and leaf-cutter bee gynandromorphs, with an updated review (Hymenoptera, Apoidea). *Zoosystematics and Evolution*, **88**(2): 205–214. https://doi.org/10.1002/zoos.201200017

LAGO-VILA, M., A. RODRÍGUEZ-SEIJO, D. ARENAS-LAGO, L. ANDRADE & M. F. A. VEGA (2016). Heavy metal content and toxicity of mine and quarry soils. *Journal of Soils and Sediments*, **17**(5): 1331–1348. https://doi.org/10.1007/s11368-016-1354-0

LE FÉON, V., A. LE NEVÉ & É. DUFRÊNE (2016). Premières mentions d'un cas de gynandromorphie chez *Nomada flava* PANZER, 1798 et *Nomada lathburiana* (KIRBY, 1802) (Hymenoptera, Apoidea, Apidae). *Invertébrés Armoricains*, **14**: 15–21. http://gretia.org/phocadownload/cahiers_gretia/IA14/15-21_IA14_Premieres_mentions_un_cas_de_gynandromorphie_Nomada_flava_et_Nomada_lathburiana.pdf [accessed 04 August 2024]

LÉONARD, A. & R. R. LAUWERYS (1980). Carcinogenicity, teratogenicity and mutagenicity of arsenic. *Mutation Research/Reviews in Genetic Toxicology*, **75**(1): 49–62. https://doi.org/10.1016/0165-1110(80)90027-5

LÉONARD, A., G. B. GERBER, P. JACQUET & R. R. LAUWERYS (1984). Carcinogenicity, mutagenicity, and teratogenicity of industrially used metals, pp. 59–126 . *In* KIRSCH-VOLDERS, M. (ed.) *Mutagenicity, Carcinogenicity, and Teratogenicity of Industrial Pollutants*. Springer, Boston (USA), 350 pp. https://doi.org/10.1007/978-1-4613-2643-4_3

LOMBARDO, A. & G. MARLETTA (2022). The teratologies of nudibranchs molluscs (Gastropoda: Nudibranchia): new insights. *Studia Marina*, **35**(1): 5–14. https://doi.org/10.5281/zenodo.6676705

LUCIA, M., L. J. ALVAREZ & A. H. ABRAHAMOVICH (2012). Gynandromorphism in Xylocopinae bees (Hymenoptera: Apidae): description of four new cases. *Zootaxa*, **3401**(1): 37. https://doi.org/10.11646/zootaxa.3401.1.2

LUCIA, M., S. C. VILLAMIL & V. H. GONZALEZ (2015). A gynandromorph of *Xylocopa augusti* and an unusual record of *X. iris* from Brazil (Hymenoptera: Apidae: Xylocopini). *Journal of Melittology*, **53**: 1–7. https://doi.org/10.17161/jom.v0i53.4979

MICHENER, C. D. (2007). *The Bees of the World*. 2nd edition. The John Hopkins University Press, Baltimore (USA), 953 pp.

MICHEZ, D., P. RASMONT, M. TERZO & N. J. VEREECKEN (2009). A synthesis of gynandromorphy among wild bees (Hymenoptera: Apoidea), with an annotated description of several new cases. *Annales de la Société entomologique de France (N.S.)*, **45**(3): 365–375. https://doi.org/10.1080/00379271.2009.10697621

MICHEZ, D., P. RASMONT, M. TERZO & N. J. VEREECKEN (2019). *Hymenoptera of Europe.* ***1.*** *Bees of Europe*. NAP éditions, Verrières-le-Buisson (France), 547 pp.

NARITA, S., R. A. S. PEREIRA, F. KJELLBERG & D. KAGEYAMA (2010). Gynandromorphs and intersexes: potential to understand the mechanism of sex determination in arthropods. *Terrestrial Arthropod Reviews*, **3**(1): 63–96. https://doi.org/10.1163/187498310x496190

OGBONNA, P. C., R. EMEA & J. A. T. DA SILVA (2011). Heavy metal concentration in soil and woody plants in a quarry. *Toxicological & Environmental Chemistry Reviews*, **93**(5): 895–903. https://doi.org/10.1080/02772248.2011.564361

PÉREZ-IÑIGO MORA C. (1982). Sobre dos interesantes casos teratológicos en Apoideos (Hym. Apoidea). *Boletín de la Asociación española de Entomología*, **6**: 29–31.

ROGERS, D. C., V. COTTARELLI & F. MARRONE (2021). New gynandromorph records for *Chirocephalus diaphanus* (Branchiopoda, Anostraca, Chirocephalidae). *Zoodiversity*, **55**(6): 459–466. https://doi.org/10.15407/zoo2021.06.459

SCHENCK, A. (1871). Einige bienen-hermaphroditen. *Entomologische Zeitung Stettin*, **32**: 335. https://www.zobodat.at/pdf/Entomologische-Zeitung-Stettin_32_0335.pdf [accessed 04 August 2024]

SCHINDLER, M., M. M. HOFMANN, D. WITTMANN & S. S. RENNER (2018). Courtship behaviour in the genus *Nomada* – antennal grabbing and possible transfer of male secretions. *Journal of Hymenoptera Research*, **65**: 47–59. https://doi.org/10.3897/jhr.65.24947

SMIT, J. (2018). *Identification key to the European species of the bee genus* Nomada *SCOPOLI, 1770 (Hymenoptera: Apidae), including 23 new species*. *Entomofauna*, **Monographie 3**: 1–253 pp. https://www.zobodat.at/pdf/ENT_M3_0001-0253.pdf

[accessed 04 August 2024]

Suzuki, K. M., D. C. Giangarelli, D. G. Ferreira, W. Frantine-Silva, S. C. Augusto & S. H. Sofia (2014). A scientific note on an anomalous diploid individual of *Euglossa melanotricha* (Apidae, Euglossini) with both female and male phenotypes. *Apidologie*, **46**(4): 495–498. https://doi.org/10.1007/s13592-014-0339-5

Tsuneki K. (1975). A partial gynandromorph appeared in the cuckoo bee *Nomada* sp. (Hymenoptera, Apidae). *Kontyû*, **43**(2): 173–180.

Wcislo, W. T., V. H. Gonzalez & L. Arneson (2004). A review of deviant phenotypes in bees in relation to brood parasitism, and a gynandromorph of *Megalopta genalis* (Hymenoptera: Halictidae). *Journal of Natural History*, **38**(11): 1443–1457. https://doi.org/10.1080/0022293031000155322

Webster, W.S. (1990). The teratology and developmental toxicity of cadmium, pp. 255–282. *In* Kalter, H. (ed.). *Issues and Reviews in Teratology*. Springer, Boston (USA), 344 pp. https://doi.org/10.1007/978-1-4613-0521-7_6