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The spread of two alien species of assassin bugs, *Zelus renardii* Kolenati, 1857 and *Nagusta goedelii* (Kolenati, 1857) (Hemiptera: Heteroptera: Reduviidae) in Sardinia (Italy)

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Abstract. The distribution of the two alien species, *Zelus renardii* Kolenati, 1857 and *Nagusta goedelii* (Kolenati, 1857) in Sardinia is summarized and commented, with the addition of some new records, including the first populations of *Z. renardii* in the northern and central-west of the island (Sassari and Oristano) and the first finding of *N. goedelii* in central-east Sardinia (Nuoro). Further considerations on the possible pathways of the two taxa are made, and the current distribution of the two species in Italy is also discussed.

Key words: alien species, citizen science, distribution, introduction, invasive species, Mediterranean, *Nagusta goedelii*, *Zelus renardii*, new records.

Introduction

Zelus renardii Kolenati, 1857 is a species of assassin bug (Hemiptera: Heteroptera: Reduviidae) native to Central and North America and introduced in many areas of the world, including Europe, where it is rapidly expanding significantly in its Mediterranean portion (Pinzari et al. 2018, Kment & van der Heyden 2022; see also van der Heyden 2023).

In Italy, this alien species was recorded in 2013 for Lazio (Dioli 2013), in 2014 for Apulia (Cornara et al. 2016, Pinzari et al. 2018, Lahbib et al. 2022), in 2018 for Basilicata (Battaglia & Mele 2020), in 2020 for Liguria, Campania, Sicily (Bella 2020) and Sardinia (Rattu & Dioli 2020), in 2021 for Emilia-Romagna (Luthi 2021), and in 2022 for Tuscany, including the island of Pianosa (van der Heyden & Nava 2022; Cianferoni 2023). Further data, also for other Italian regions (e.g., in Northern and Southern Italy), are available on the platform "iNaturalist" (www.inaturalist.org), in part accessible also through GBIF (iNaturalist contributors, iNaturalist, 2022), and the naturalistic forum "Natura Mediterraneo" (www.naturamediterraneo.com).

A contribution summarizing the Italian distribution with additional unpublished records is in preparation (Cianferoni et al., in prep.).

In Sardinia, the species was recorded for the first time by Rattu & Dioli (2020) based on a single specimen collected on 27 July 2020 in Quartu Sant'Elena (Cagliari), in the South of the island. After that date, new observations from Cagliari and its surroundings were uploaded to iNaturalist, from 2020 to 2022, both in summer and autumn.

Nagusta goedelii (Kolenati, 1857) is another species of Reduviidae occurring from Central Asia to South-eastern Europe. For at least a century it has been spreading westwards, with an increase in spreading in recent years across Central and Southern Europe (Cianferoni et al. 2021).

In Italy, this species has been recorded so far in 2007 in Abruzzo (Olivieri 2011) and Emilia-Romagna (Dioli 2014), in 2010 in Tuscany (Dioli 2014), and in 2020 in Sardinia (Cianferoni et al. 2021). Further data are available from "iNaturalist" (www.inaturalist.org), in part accessible also through GBIF (iNaturalist contributors, iNaturalist, 2022). Other web resources, i.e., "Forum Entomologi Italiani" (www.entomologiitaliani.net), "Natura Mediterraneo" (www.naturamediterraneo.com) were generically quoted by Luthi & Dioli (2020) and Cianferoni et al. (2021): the species occurs in all the regions of Northern (except for Aosta Valley) and Central Italy. In Southern Italy, the diffusion is still ongoing (Cianferoni et al. 2021): it has been reported so far only for Basilicata (Cianferoni et al. 2021), but unpublished records for other regions are available from the sources mentioned above (see below for distribution details).

In Sardinia, the species was recorded for the first time by Cianferoni et al. (2021) based on specimens from Sassari, north of the island (23 October and 19 November 2020).

Here, we give new records of *Z. renardii* and *N. goedelii* from other sites in Sardinia.

Material and methods

For each record, the following information is given: country, region, locality, collecting site, geographical coordinates (decimal degrees; the WGS84 datum), date, collector, number of specimens, possibly sex and life cycle stage. In the text, both the term immature and nymph are used in the sense of Rédei & Štys (2016) to indicate preimaginal stages.

All the specimens were collected beating (with an entomological umbrella) on different species of plants (see material examined).

All material is preserved in the invertebrate collection of the National Research Council (CNR), Research Institute on Terrestrial Ecosystems (IRET), currently hosted in the Natural History Museum of the University of Florence, "La Specola", Florence (Italy). In the same collection of CNR is transferred even the female adult specimen of *N. goedelii* collected in Sassari (in the Court of Appeal, 40.710556° N 8.550833° E), on 19 November 2020, which has been dry-mounted. The specific identification of the collected material, in addition to external morphology, was verified even through the study of male genitalia.

Further data on these species concerning distribution come from the platform "iNaturalist", the system for sharing biodiversity records (www.inaturalist.org), in part accessible also through GBIF (iNaturalist contributors, iNaturalist, 2022), and the Italian naturalistic forums "Natura Mediterraneo" (www.naturamediterraneo.com) and "Forum Entomologi Italiani" (www.entomologiitaliani.net). All these citizen science records were checked and validated by examination of the available image(s). However, no misidentification was found.

The subgenus assignment for *Z. renardii* is not considered here since nomenclatural problems and lack of data support for the subgeneric classification exist. A dedicated contribution is currently under review (Cianferoni).

Results

Zelus renardii Kolenati, 1857

Material examined: ITALY**,** Sardinia: Sassari, "Site 2", 40.731044° N 8.561336° E, on *Ailanthus altissima* (Mill.) Swingle, 10.IX.2022, L. Loru leg., 1 adult ♀, dry preserved; *idem*, 20.IX.2022, L. Loru leg., 1 adult ♂ and 1 adult ♀, dry preserved; *idem*, 30.X.2022, L. Loru leg., 1 adult ♀, 70% ethanol preserved. Oristano, 39.91192° N 8.59982° E, on *Cercis siliquastrum* L., 9.VI.2023, A. Pes legit, 1 adult, 70% ethanol preserved; *idem*, on *C. siliquastrum*, 6.VII.2023, L. Loru & S. Flore leg., 2 adults, 2 immatures, 70% ethanol preserved; *idem*, on *C. siliquastrum*, 14.VII.2023, L. Loru leg., 1 immature, 70% ethanol preserved; *idem*, on *Styphnolobium japonicum* (L.) Schott, 2.VIII.2023, S. Flore leg., 1 immature, 70% ethanol preserved; *idem*, on *C. siliquastrum* and *S. japonicum*, 7.IX.2023, L. Loru & S. Flore leg., 3 immatures, 70% ethanol preserved; Oristano, countryside north of the city, 39.92821° N 8.59300° E, on *Pyrus communis* L., 4.VII.2023, S. Flore & A. Pes leg., 2 immatures, 70% ethanol preserved; *idem*, on *P. communis*, 7.IX.2023, L. Loru & S. Flore leg., 1 adult, 6 immatures, 70% ethanol preserved. Cagliari, 39.22217° N 9.11522° E, on *Quercus ilex* L., 20.VI.2023, S. Flore leg., 1 adult, photo by L. Loru.

Distribution in Italy: This species is known from Northern, Central and Southern Italy, including Sicily and Sardinia (see references in the Introduction). Nonetheless, it is not known for all the Italian regions; data for some of them are still formally unpublished and are available from the web sources mentioned above. A more detailed synopsis is currently in preparation (Cianferoni et al., in prep.).

Distribution in Sardinia (Fig. 1): *Zelus renardii* is known from some observations from Cagliari and its surroundings in the southern part of the island (see Rattu & Dioli 2020 and iNaturalist) and from Sassari (see the new records above), in northern Sardinia.

Nagusta goedelii (Kolenati, 1857)

Material examined: ITALY**,** Sardinia: Sassari, "Site 1", 40.737811° N 8.560475° E, on *Ailanthus altissima* (Mill.) Swingle, 25.VI.2022, L. Loru leg., 1 V instar immature, 70% ethanol preserved; *idem*, 16.IX.2022, L. Loru leg., 1 adult ♂ and 1 adult ♀, dry preserved; Sassari, "Site 2", 40.731044° N 8.561336° E, on *Ailanthus altissima*, 10.IX. 2022, L. Loru leg., 1 adult ♀, 70% ethanol preserved. Nuoro, 40.320794° N 9.334308° E, 7.IX.2023, L. Loru leg., 1 adult ♀, 70% ethanol preserved.

Distribution in Italy: This species is known from all the regions of Northern Italy (except the Aosta Valley) and Central Italy (a new observation for Umbria from 2022 is available on iNaturalist). In Southern Italy, it was recorded since 2018 in Basilicata (see Cianferoni et al. 2021) and recently observed since 2022 in Apulia and since 2023 in Molise (iNaturalist). In Sardinia recorded since 2020 (see below).

Distribution in Sardinia (Fig. 1): *Nagusta goedelii* is currently known only based on records from Sassari, in the north of the island (Cianferoni et al. 2021).

Discussion

Considering the data currently available, *Z. renardii* shows three apparently disjointed distribution cores: the first one around Cagliari (southern Sardinia), with observations from July 2020, another one in Sassari (northern Sardinia), with records from September 2022 (see material examined above), and a third one

from Oristano (central-western Sardinia), with records from June 2023.

Therefore, it is possible that these populations originated from different passive introductions on the island (possibly through goods transiting from ports or airports) and then (at least in part) having been transported by land with goods or accidental transport (the three sites are well connected by the main communication route on the island: the European route E25). However, it cannot be excluded that also the specimens occurring in Sassari may originate from a passive introduction (by land) starting from the first population of Cagliari. Only further investigation with molecular analyses could clarify the origin of the core of *Z. renardii* occurring in the northern of the island (and, more in general, the origin of the Sardinian populations).

Observations of early instar immature specimens of *Z. renardii* are available from Cagliari (2021 and 2022; iNaturalist) and from Oristano (2023; this contribution), demonstrating that the species is now reproducing in the southern-central part of the island but maybe not yet from Sassari.

Concerning *N. goedelii* instead, the only known population is from Sassari, where it was recorded for the first time in October 2020 and then collected again until 2023, but the species is also known from Nuoro (in central-east Sardinia) from a single female specimen collected in September 2023. Considering even the absence of data from the web sources mentioned before, this species could be currently confined only to the north-central part of the island.

Introduction pathways are unknown, even if a passive transport through goods can be hypothesized as the most probable. However, the same assumptions previously listed for *Z. renardii* can be applied. Also in this case, genetic studies would be necessary to identify the origin of this population.

A single last instar nymph of *N. goedelii* is here recorded from Sassari (June 2022), suggesting that the species probably already breeds in the city, even in truth, direct introductions from the continent cannot be excluded in the absence of further data.

In northern Sardinia, the two reduviids, both generalist predators, were observed in co-occurrence with the invasive pentatomid *Halyomorpha halys* (Stål, 1855), which recently colonized the island (Loru et al. 2018; see Cianferoni et al. 2018, 2019 for general distribution review). In fact, *N. goedelii* can potentially attack even the eggs and first instar nymphs of *H. halys* (Bulgarini et al. 2020), and it is not excluded for *Z. renardii*. If this interaction is confirmed, the consequences must be carefully evaluated.

Even if predation on allochthonous invasive species may appear positive at first sight, the biocenotic relationships that two generalist alien predators will establish with the native species are still unpredictable.

All the specimens from Sassari were collected beating on the allochthonous plant *A. altissima*. However, this was a focused search to find specimens of *H. halys*, which is a polyphagous pentatomid (Cianferoni et al. 2018), neither the two predatory species are linked with the plant. The specimens from Oristano and Cagliari were collected beating on other plant species indeed or directly capturing a freely roaming specimen in the case *of N. goedelii* from Nuoro (see material examined).

Finally, we give some considerations on the Italian distribution of the two species. Based on data available (in particular from iNaturalist) it is evident that both species are limited by low temperatures, remaining confined to lowlands or penetrating only valleys in the Alpine area. This pattern is evident at least in the case of *N. goedelii* (for *Z. renardii* the data for Northern Italy is still too limited). However, similar considerations can be made on the Apennines (where this distribution is precise for both species). The absence of records for *N. goedelii* from the Aosta Valley is so easily explained; even if the colonization of the lower altitudes cannot be excluded (especially with global warming).

In continental Italy, *Z. renardii* has probably been subject to multiple introductions starting from large cities (see, e.g., Pinzari et al. 2018 and iNaturalist), making its distribution still fragmented throughout the country. On the contrary, *N. goedelii* shows a more continuous distribution in continental Italy, and its expansion is proceeding southward. It is absolutely obvious that it will be observed soon (if not already is) in new southern regions, such as Campania, Calabria, and possibly Sicily.

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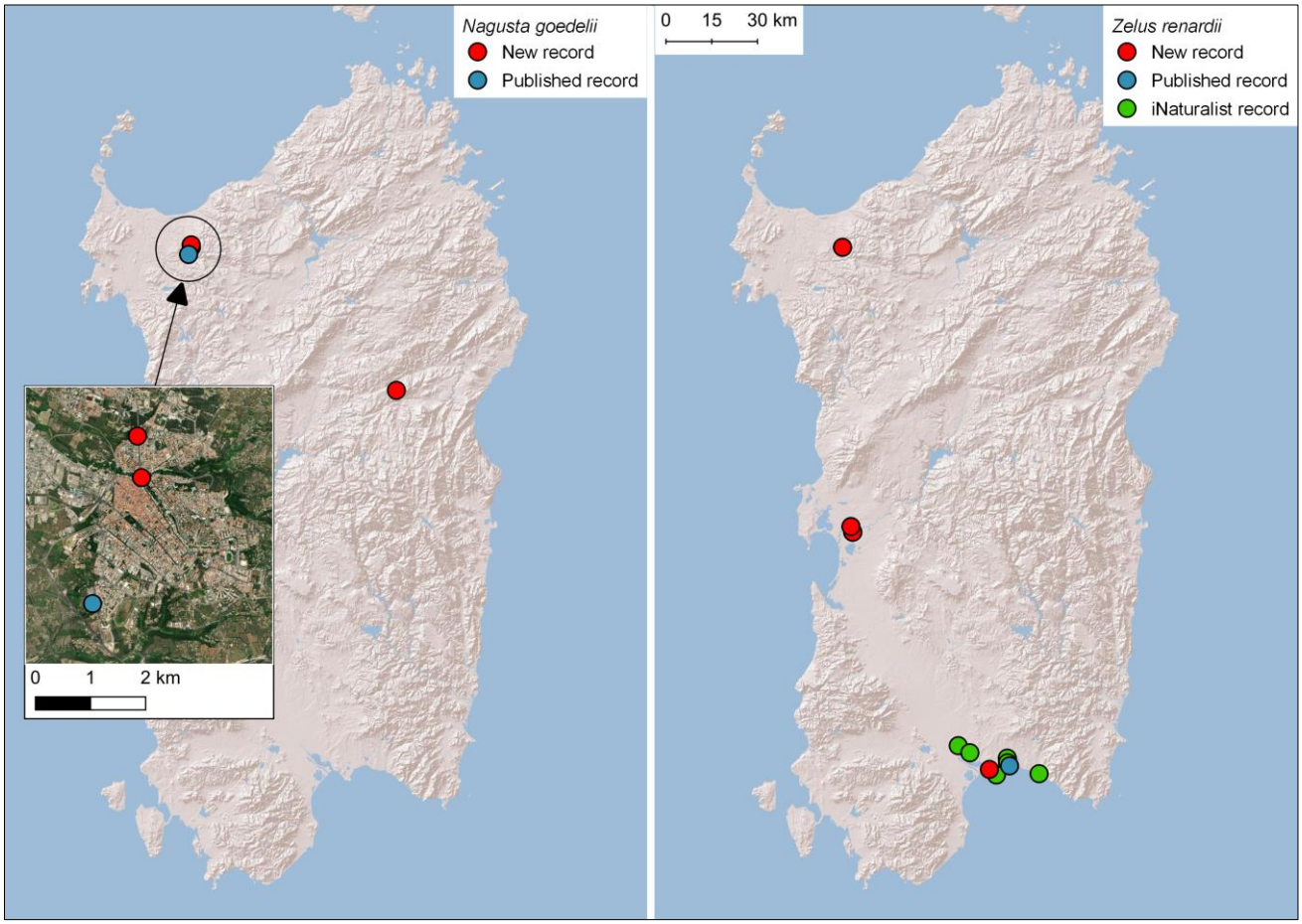

Fig. 1. Distribution of *Nagusta goedelii* (Kolenati, 1857) and *Zelus renardii* Kolenati, 1857 in Sardinia.

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