SAPIENZA
UNIVERSITÀ EDITRICE

E-ISSN 2284-4880
ISSN 0429-288X

Fragmenta entomologica, 55 (2): 161–170 (2023)

Research article
Submitted: July 17th, 2023 – *Accepted*: December 4th, 2023 – *Published*: December 21st, 2023
DOI: 10.13133/2284-4880/1528

The effects of short-term climate change on the range of species: the case of the expanding European dwarf mantis *Ameles spallanzania* in northern Italy (Mantodea: Amelidae)

Luca ANSELMO[1,*], William DI PIETRO[2], Oscar MAIOGLIO[3], Roberto BATTISTON[4]

[1] *Department of Life Sciences and System Biology, University of Turin, 10123 Turin, TO, Italy* – luca.anselmo@unito.it
[2] *World Biodiversity Association Onlus, Civic Museum of Natural History, 37129 Verona, VR, Italy* – william.dipietro10@gmail.com
[3] *Associazione Naturalistica Piemontese, Museo Civico di Storia Naturale, 10022 Carmagnola, TO, Italy* – oscamaio@gmail.com
[4] *Museum of Archeology and Natural Sciences, 36075 Montecchio Maggiore, VI, Italy* – roberto.battiston@comune.montecchio-maggiore.vi.it
* Corresponding author

Abstract
Climate change is altering the distribution of many species, which shift their range chasing the suitable conditions to survive and reproduce. Within a few years, the European dwarf mantis (*Ameles spallanzania*) seems to have expanded its range towards northern Italy, settling in the Po Valley and reaching the Alps. Our goal was to investigate the relationship between the climate of the last four decades in Italy and the distribution of this species in the current period and in the past. The results indicate that, during the last decades, a rapid and remarkable increase in climatically suitable area for this species has occurred in northern Italy, while in the historical presence sites it has remained rather constant. The existence of corridors such as railways, embankments, and roadsides may have accelerated its dispersal. These results suggest that rapid climate change, in particular the rise in average annual temperature, may contribute significantly to the rapid expansion of a thermophilic species, with hitherto unknown consequences on the ecological communities it reaches.

Key words: *Ameles spallanzania*, maxent, range expantion, neonative species, alien species.

Introduction

Climate change refers to a change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer (IPCC 2014). The human-induced warming on global scale is unequivocal and consisted of an increase of about 0.2 °C per decade from the pre-industrial period to 2017 (Allen et al. 2018). Central Europe, including Italy (Brunetti et al. 2006), is facing increasingly hot and dry summers (Seneviratne et al. 2006), and temperatures are expected to rise further during the twenty-first century (Tomozeiu et al. 2014; Bucchignani et al. 2016).

Range shift is one of the expected responses of species to climate change (Parmesan & Yohe 2003; Chen et al. 2011). As formerly unsuitable habitat becomes suitable, and vice versa, many species shift their ranges to follow changes in habitat and climate. Even among European insects, there are many examples where species have recently started both northward (Parmesan et al. 1999; Devictor et al. 2012; Mason et al. 2015) and upward (Dieker et al. 2011; Menéndez et al. 2014; Rödder et al. 2021) distributive shifts. Local conditions and microclimates are altered by climate change, sometimes in different ways, evolving discontinuously and creating peculiar local climate patterns that affect local populations (Suggitt et al. 2011, 2018; Potter et al. 2013; Battiston & Biondi 2015).

In this study we analysed the Italian distribution of the European dwarf mantis *Ameles spallanzania* (Rossi, 1792) in the last decades, a period during which the species was observed more and more frequently in northern Italy (Battiston et al. 2020a). According to Battiston et al. (2020a) this species, not migrant, tendentially sedentary and linked to warm climate, could have recently expanded its range, thanks to the recent rising temperatures and the presence of man-made corridors and human transport. We have therefore investigated the relationship between the climate of the last four decades in Italy and the distribution of this species, as a case study to investigate the influence of climate on low-mobility species between natural and human-mediated habitats.

Material and methods

Study species

The European dwarf mantis *Ameles spallanzania* is a small-sized mantis, distributed in almost all the Mediterranean basin (Battiston 2020). Females are brachypterous and tendentially sedentary while males are macropterous and able to fly over short distances (Battiston et al. 2010). The general coloration, shape of the body, and movements mimic the vegetation where this species rests and hunts. Its natural habitats are maquis, garrigue, and mediterranean steppe but it can be found as well in many arid and thermophilus discontinuity of natural vegetation inside artificial environments (unmanaged gardens, deposits, roadside verges, etc.) (Battiston et al. 2020b; Cassar 2020). This species has been recorded standing on a variety of forbs and shrubs: *Artemisia campestris* L., *Centaurea paniculata* L., *Eryngium campestre* L., *Echinops sphaerocephalus* L., *Foeniculum vulgare* L., *Lavandula* spp., *Mentha* spp., *Odontites luteus* (L.), *Salvia rosmarinus* Spenn. (= *Rosmarinus officinalis* L.), *S. officinalis* L., *Satureja* spp. (Battiston et al. 2010; Leandri et al. 2013; Anselmo 2022; WDP pers. obs.). It is also found in abandoned orchards, with a layer of *Genista umbellata* (L'Her.) Poir. and/or *Lygos sphaerocarpa* (L.) Heyw. interspersed with herbs and tall grasses (Payne 2017). Nymphs and mature females usually hide on low vegetation amongst leaves, buds or flower heads while adult males use to cling on higher stems, especially if they are following the female pheromones (Payne 2017). *A. spallanzania* is capable of adapting its lifecycle to latitude: in Mediterranean and warmer areas it can produce two generations per year, either with overwintering nymphs or with mixed populations of overwintering nymphs and oothecae; in northern and continental localities only one generation per year is produced and overwintering oothecas are able to tolerate sub-zero temperatures (Battiston & Galliani 2011).

Past and current occurrences

According to the historical checklist and distribution of the Italian fauna (Fontana et al. 2005), the past distribution of *A. spallanzania* was mainly concentrated near the West inland coastline and in the islands, referring to 99 generically indicated localities from 1878 to 2001 (grouped in 77 UTM square cells of 10 x 10 km). Among these data, those falling in northern Italy refer mainly to the western part, near the Ligurian coast and the nearby inland, while to the East only two occurrences were recorded in 1963 and

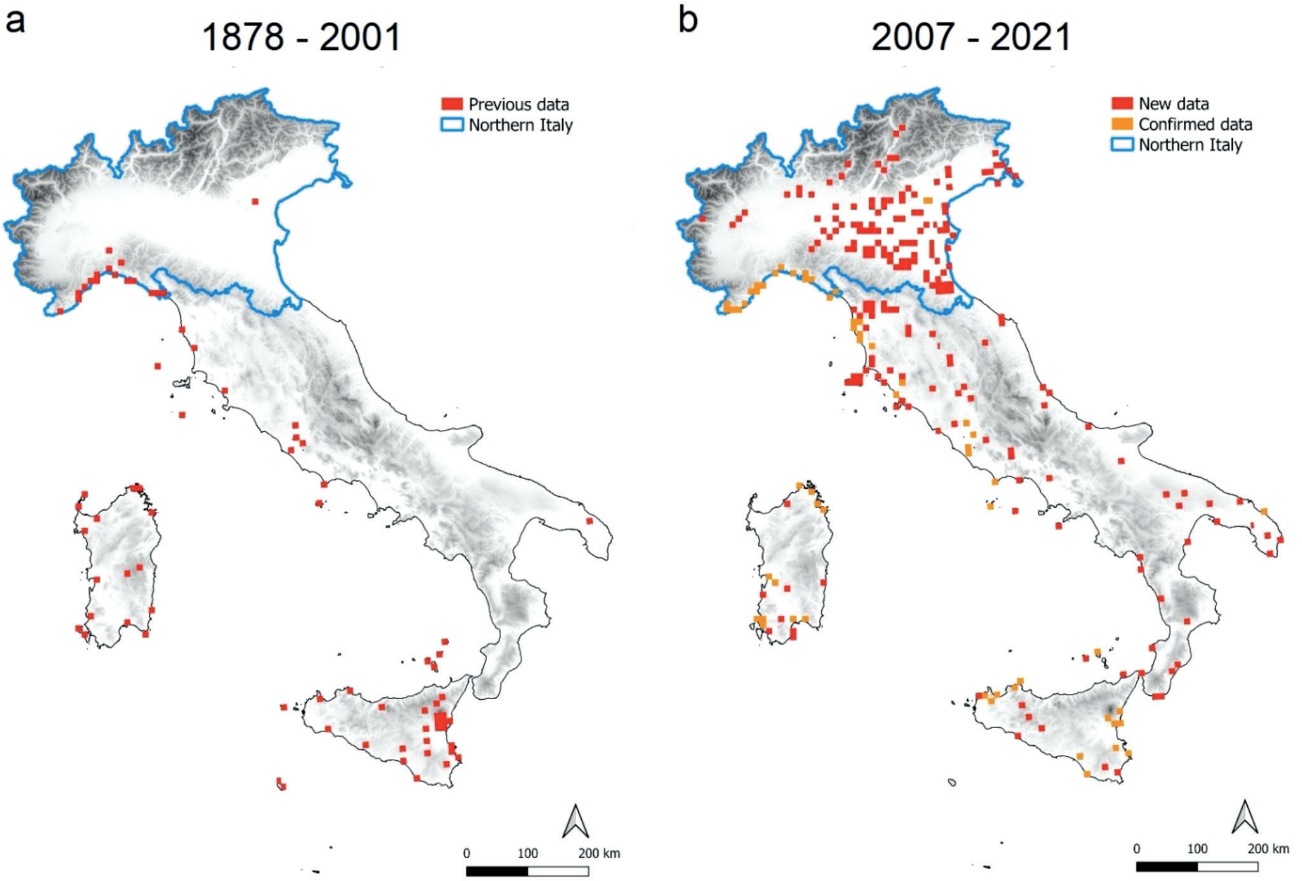

Fig. 1 – Distribution of *Ameles spallanzania* in Italy across **a**, past period and **b**, current period. Confirmed data refer to already known presence cells in the previous time interval.

1969 in the Province of Padova (Fig. 1a). Subsequently, the presence of this species was recorded more and more frequently in northern Italy (Cogo & Battiston 2007; Battiston & Buzzetti 2012; Uliana & Battiston 2012; Leandri et al. 2013; Buzzetti et al. 2018; Battiston et al. 2020a; Battiston 2021), even in the Alps (Ballini & Wilhelm 2014; Tabarelli de Fatis & Debiasi 2020; Anselmo 2022). We then gathering overall 401 georeferenced data from 2007 to 2021 (Fig. 1b) available from the aforementioned literature, GBIF (https://doi.org/10.15468/dl.ggb4u5), iNaturalist (https://www.inaturalist.org), data collected by the authors also through the "Segnala una mantide" (= "Report a mantis!") of Mantidi Lovers Italia citizen science project (https://www.facebook.com/MantidiLoversItalia). We only selected data and with a precision lower than 300 m.

Climatic variables

For the purposes of our study, high resolution layers of monthly precipitation amount, maximum and minimum temperature from 1980 and 2019 were obtained from the CHELSA V2.1 database (Karger et al. 2017, 2021), with original resolution on Italy of about 655 m. These data were averaged over 10-year subsets and used to produce 19 bioclimatic variables for each, with the package dismo v. 1.3-9 (Hijmans et al. 2022) in the software R v. 3.6.3 (R Core Team 2020). A selection of climatic variables from the decade 2010-2019 was carried out (Merow et al. 2013; Fourcade et al. 2018), identifying the groups of variables most correlated (Spearman correlation > 0.7) with the package ENMTools v. 1.0.6 (Warren et al. 2021) and choosing the supposed most ecologically important variable for each group (Forcaude et al. 2018). The resulting set of variables from this procedure were bio1 (mean annual temperature), bio2 (mean diurnal temperature range), bio8 (mean daily temperatures of the wettest quarter), bio15 (precipitation seasonality) and bio19 (mean monthly precipitation amount of the coldest quarter). No land cover variables were used, as this species is capable of settling in marginal small microhabitats (e.g. roadsides) possibly present within almost any land cover and above. Furthermore, these microhabitats are not identifiable at the same resolution of the climatic variables.

Species distribution modelling

The modelling was performed with the package Biomod2 v. 3.5.1 (Thuiller et al. 2021) in R. Individual models were built with the MaxEnt algorithm (Phillips et al. 2006), a machine learning method that applies the principle of maximum entropy to predict the potential distribution of species from presence-only data (Elith et al. 2011; Phillips & Dudík 2008). Compared to other methods, this algorithm is more efficient and reliable (Elith et al. 2006; Guisan et al. 2007; Peterson et al. 2007), providing useful results even with small samples (Pearson et al. 2006; Wisz et al. 2008) and is less influenced by unequal sampling levels (Tsoar et al. 2007). The models were built using one occurrence per pixel referred to the current period (2007-2021) resulting in 325 points, and the climatic variables referred to the current period (2010-2019) prepared as described in the previous steps. In the modelling procedure a random sample of 10‘000 pseudo-absences were generated across the study area. To evaluate model performance, the algorithm was calibrated with 80% of the data and tested with the remaining 20%. The procedure was replicated 10 times and each model was evaluated by the Area Under the Curve (AUC) and the True Skill Statistic (TSS): Models with AUC below 0.6 are not considered reliable, 0.6-0.7 are considered poor, 0.7-0.8 right, 0.8-0.9 good and higher than 0.9 excellent (Arújo et al. 2005). Models with TSS measures below 0.4 are considered poor, 0.4-0.8 useful, and higher than 0.8 good-excellent (Allouche et al. 2006). An ensemble model was created by averaging the individual models, trained on the 10 sampling replicates, and then projected in the current period and in each past decade in order to obtain suitability maps through time (with suit-

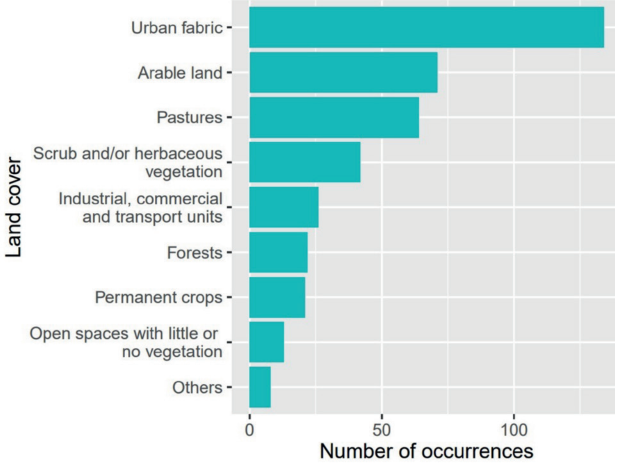

Fig. 2 – Land use in the occurrences of the current period.

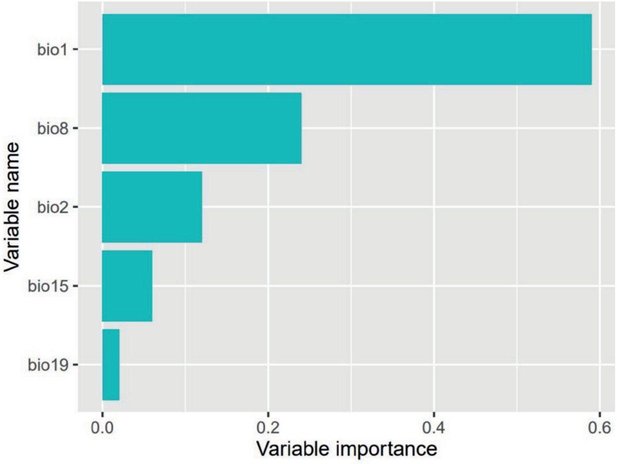

Fig. 3 – Importance of climatic variables used to model the distribution of *Ameles spallanzania.*

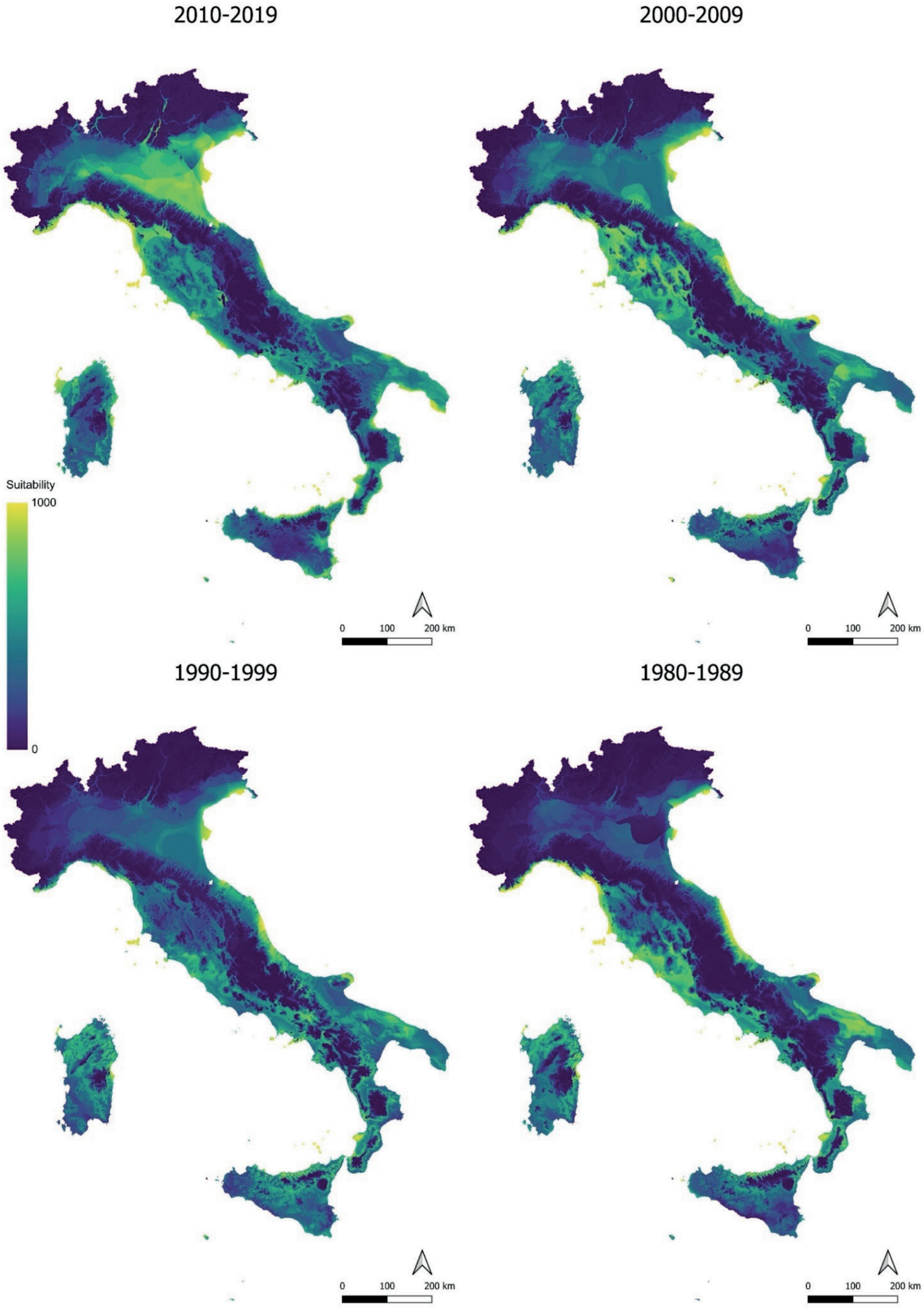

Fig. 4 – Suitability maps of *Ameles spallanzania* referred to each decade.

ability values from 0 to 1000), also building binary projections of presence-absence (1 for presence and 0 for absence) using the threshold that maximizes the TSS scores, with the Biomod2 package (Thuiller et al. 2021).

Distribution analysis

We evaluated the change of distribution of *A. spallanzania* in the last four decades, in terms of predicted suitability and predicted presence area with the package raster v. 3.5-15 (Hijmans 2022) in R. The areas on which the comparison was carried out corresponds to northern Italy (i.e. the merging of the administrative regions Valle d'Aosta, Piedmont, Lombardy, Trentino-Alto Adige, Veneto, Friuli-Venezia Giulia, Liguria and Emilia-Romagna) and to the historical range, i.e. the 10 x 10 km presence cells provided 10 x 10 km cells provided in the checklist and distribution of the Italian fauna (Fontana et al. 2005).

For descriptive purposes, the land cover in the occurrences related to the current period was reported, based on CORINE Land Cover 2018 (CLC) produced by the Copernicus Land Monitoring Service (Büttner et al. 2021).

Results

The performance of the models was deemed sufficient to consider reliable the predictions and carry out the distribution analyses, as they showed AUC greater than 0.7 (mean = 0.79, SD = 0.02) and TSS greater than 0.4 (mean = 0.46, SD = 0.05). The most important variables driving the distribution of *A. spallanzania* were the temperature variables, in particular the mean annual temperature (bio1) showed the greatest influence (Fig. 3). In contrast, the precipitation-derived variables (bio15 and bio19) were not of great importance. The suitability of northern Italy for this species has gradually increased over the decades (Figs 4-5), from the mean value of 111.3 (SD = 158.7) referred to the decade 1980-1989 to 295.4 (SD = 300.8) of the last decade. In this geographical context, the presence area indicated by the binomial transformation of the suitability map has also greatly increased over time, from 3553.3 km^2 to 30385.4 km^2 between the first and last decade considered (Fig. 6). In comparison, the suitability within the historical distribution cells has only slightly increased over time (Fig. 5), showing a mean value of 370.2 (SD = 272.3) in the first decade and of 494.75 (SD = 271.61) in the last decade, and so has the predicted presence area, from 1589.4 km^2 to 2082.1 km^2 (Fig. 6).

Based on the CLC, the occurrences in the current period fell mostly on the urban fabric (N = 134), followed by other more natural land covers (Fig. 2).

Discussion

The efficiency of the models built only with climatic variables demonstrates that these were of great importance in the distribution of *Ameles spallanzania*. The average annual temperature plays a fundamental role in predicting the distribution of this species and its recent rise (WMO 2022) may explain the increase of its observations in northern Italy. The low importance of the variables related to rainfall instead suggests that this species can survive even in places with a not distinctly Mediterranean climate and therefore, *A. spallanzania* should be considered a thermophilic species rather than a xero-thermophilic species. According to the models, while habitat suitability has remained quite similar over time within areas of historical presence, it has much increased in northern Italy (+62.3% since the 1980s; average inter-decade increase of 27.9%, SD = 1.7%). The area of potential presence has also increased considerably in northern Italy (+88.3% since the 1980s;, average inter-decade increase of 43.4%, SD = 38.3%). These results suggest a rapid expansion of this species due to the progressive gain in the climatically suitable area, especially

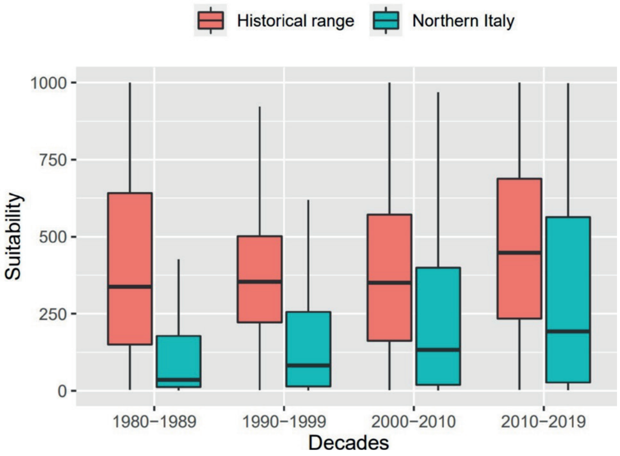

Fig. 5 – Boxplots of suitability per decade referred to the historical range and northern Italy.

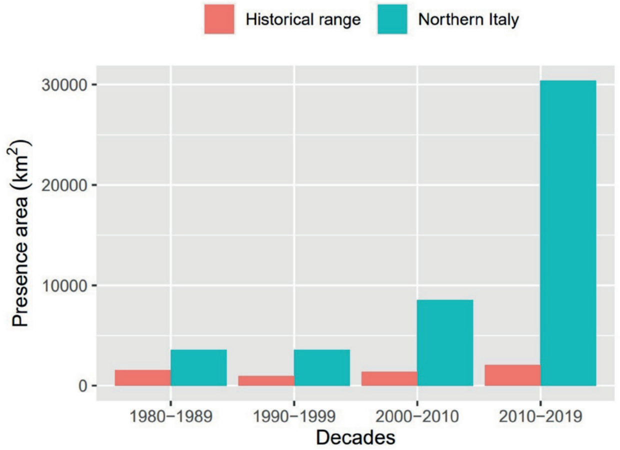

Fig. 6 – Extent of predicted presence areas derived from binary maps.

occurred in the last decade 2010-2019. The rapidity with which this low-mobility species has expanded (considering females are unable to fly), could be linked to the use of roadsides or railway embankments as corridors for active dispersal; additionally, the use of wagons or ornamental plants for laying oothecae has also been hypothesized (Battiston & Buzzetti 2012; Battiston et al. 2020a). However, it should be emphasized that these surrogate habitats that may have been most involved in the dispersal of *A. spallanzania* (i.e. the railways embankments) have existed with the same arrangement for a long time (Battiston et al. 2020a). Therefore, assuming a higher survival of the species due to the increased climatic suitability in new areas, the presence of these pre-existing corridors may have only facilitated its expansion. Furthermore, by preferring habitats with scarce and sometimes degraded vegetation (Battiston et al. 2020b; Cassar 2020; Anselmo 2022), *A. spallanzania* could perhaps have easily found suitable environments in the urbanized areas, e.g. along the communication routes. In this sense the land cover of the urban fabric, coinciding with the 33.5% of the occurrences recorded from 2007 to 2021, seems to confirm this ability.

Based on the results obtained from this study, a further northward and upward expansion of *A. spallanzania* and the formation of stable populations could be foreseen in northern Italy and perhaps in the rest of Europe, where the temperatures are rapidly rising almost everywhere (WMO 2022). The recent finding of this species in other localities further north of the range known seems confirm this trend, i.e. in Germany (Schwarz & Ehrmann 2018), France and Switzerland (Borer et al. 2023).

Our results suggest that a short-term climate change occurred within a few decades may contribute significantly to the expansion of a thermophilic species, with unknown consequences on the ecological communities reached by it. Climate change is already altering the distribution of many species (Lenoir & Svenning 2015) and will continue in the near future, increasingly blurring the distinction between those species traditionally considered native and non-native (Thomas & Ohlemüller 2010, Essl et al. 2019). How much human-induced climate change compares to unintentional or deliberate human introduction in favouring the expansion of species? A critical analysis of the concepts that distinguish alien species from native species (Richardson et al. 2000, 2011; Battiston et al. 2017; Essl et al. 2018) and the extent of their threat to biodiversity (Pyšek et al. 2020) may be increasingly necessary. In the case of *A. spallanzania*, anthropogenic climate change could reduce or eliminate the biogeographic barriers which have so far precluded survival and reproduction in areas geographically contiguous to its native range. This same mechanism will be essential to the survival of many imperilled species, which will be able to survive climate change only by expanding outside their historical ranges (Thomas & Ohlemüller 2010). From this perspective, the northward expansion of *A. spallanzania* in response to anthropogenic climate changes and human mediated actions, would correspond at least in part to the definition proposed by Essel et al. (2019, 2021) of "neonative" species, i.e. range-expanding species that track environmental changes without human assistance. Only through further research will it be possible to determine the extent to which this species may affect the new recipient ecosystems.

Acknowledgments – We would like to thank the contributors to the citizen science, which provided a large amount of data useful for carrying out the analyses. We also warmly thank our colleague Prof. Moreno Di Marco (Sapienza University, Rome) for useful comments and suggestions on a previous version of our article, which certainly contributed to improving its quality.

References

Allen M.R., Dube O.P., Solecki W., Aragón-Durand F., Cramer W., Humphreys S., Kainuma M., Kala J., Mahowald N., Mulugetta Y., Perez R., Wairiu M., Zickfeld K. 2018. Framing and Context. In: Masson-Delmotte V., Zhai P., Pörtner H.O., Roberts D., Skea J., Shukla P.R., Pirani A., Moufouma-Okia W., Péan C., Pidcock R., Connors S., Matthews J.B.R., Chen Y., Zhou X., Gomis M.I., Lonnoy E., Maycock T., Tignor M., Waterfield T. (eds) Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp 49–92; Doi: 10.1017/9781009157940.003

Allouche O., Tsoar A., Kadmon R. 2006. Assessing the accuracy of species distribution models: prevalence, kappa and the true skill statistic (TSS). Journal of applied ecology, 43: 1223–1232.

Anselmo L. 2022. First records of *Ameles spallanzania* in the Western Alps and habitat preferences. Bulletin of Insectology, 75: 157–160.

Araújo M.B., Pearson R.G., Thuiller W., Erhard M. 2005 Validation of species-climate impact models under climate change. Global Change Biology, 11: 1504–1513; Doi: 10.1111/j.13652486.2005.01000.x

Ballini S., Wilhalm T. 2014 *Ameles spallanzania* (Rossi, 1792) (Insecta, Mantidae, Amelinae): neu für die Region Trentino-Südtirol. Gredleriana, 14: 271–274.

Battiston R., Picciau L., Fontana P., Marshall J. 2010. The mantids of the Euro-Mediterranean area. WBA Handbooks 2, Verona, Italy, 240 pp.

Battiston R., Galliani C. 2011. On the life-cycle of *Ameles spallanzania* (Rossi, 1792) (Insecta, Mantodea). Atti della Società Italiana di Scienze Naturali e del Museo Civico di Storia Naturale di Milano, 152 (1): 25–35.

Battiston R., Buzzetti F.M. 2012. Segnalazioni di insetti rari e termofili in Veneto: nuovi corridoi ecologici e strategie di colonizzazione in ambienti antropizzati (*Reticulitermes lucifugus, Ameles spallanzania, Acrida ungarica, Libelloides longicornis*). Natura Vicentina, 15: 85–94.

Battiston R., Biondi S. 2015. Pullulazioni entomologiche e dinamiche di popolazione estreme: il caso della presenza di *Calosoma* Weber, 1801 (Insecta, Coleoptera) in Veneto. Natura Vicentina, 18: 5–14.

Battiston R., Andria S., Ruzzante G. 2017. The silent spreading of a giant mantis: a critical update on the distribution of *Sphodromantis viridis* (Forskål, 1775) in the Mediterranean islands (Mantodea: Mantidae). Onychium, 13: 25–30

Battiston R. 2020. *Ameles spallanzania*. The IUCN Red List of Threatened Species: e.T44791655A44798440; Doi: 10.2305/IUCN.UK.2020-2.RLTS.T44791655A44798440.en

Battiston R., Giovanni B., Corradi L., Dall'Ó M., Glerean P., Morin L., Pesarini S., Tabarelli De Fatis K., Tami F. 2020a. Rotta a Nord-Est: l'espansione dell'*Ameles spallanzania* (Rossi, 1792) nell'Italia Nord-Orientale. Studi Trentini di Scienze Naturali, 99: 9–13.

Battiston R., Di Pietro W., Amerini R., Sciberras A. 2020b. The praying mantids (Insecta: Mantodea) as indicators for biodiversity and environmental conservation: a case study from the Maltese and Balearic archipelagos. Biodiversity, 21 (3): 142–149.

Battiston R. 2021. Insecta Mantodea. In: Bologna M.A., Zapparoli M., Oliverio M., Minelli A., Bonato L., Cianferoni F., Stoch F. (ed.) Checklist of the Italian Fauna. Version 1.0. Last update: 2021-05-31. Available at: https://www.lifewatchitaly.eu/en/initiatives/checklist-fauna-italia-en/checklist/

Borer M., Delarze R., Monnerat C. 2023. Premières données d'*Ameles spallanzania* (Rossi, 1792) pour la Suisse (Mantodea: Mantidae). Entomo Helvetica, 16: 209–214.

Brunetti M., Maugeri M., Monti F., Nanni T. 2006. Temperature and precipitation variability in Italy in the last two centuries from homogenised instrumental time series. International Journal of Climatology, 26: 345–381; Doi: doi.org/10.1002/joc.1251

Bucchignani E., Montesarchio M., Zollo A.L., Mercogliano P. 2016. High-resolution climate simulations with COSMO-CLM over Italy: performance evaluation and climate projections for the 21st century. International Journal Climatology, 36: 735–756; Doi: 10.1002/joc.4379

Büttner G., Kosztra B., Maucha G., Pataki R., Kleeschulte S., Hazeu G., Vittek M., Schröder C., Littkopf A. 2021. Copernicus Land Monitoring Service - CORINE Land Cover - User manual. Copernicus Land Monitoring Service (CLMS), European Environment Agency (EEA), Denmark, Copenhagen, 128 pp.

Buzzetti F.M., Fontana P., Marangoni F., Molinaro G., Battiston R. 2018. Interessanti presenze di Ortotteroidei (Insecta: Orthoptera, Dermaptera, Mantodea) nel Vicentino. Natura Vicentina, 21: 51–55.

Cassar T. 2020. The praying mantises of the Maltese Islands: distribution and ecology (Mantodea). Fragmenta entomologica, 52 (2): 341–348.

Chen I.C., Hill J.K., Ohlemüller R., Roy D.B., Thomas C.D. 2011. Rapid range shifts of species associated with high levels of climate warming. Science, 333: 1024–1026; Doi: 10.1126/science.1206432

Cogo A., Battiston R. 2007. Nuovi dati sulla distribuzione di *Ameles spallanzania* (Rossi, 1792) in Italia (Insecta Mantodea, Amelinae). Natura Vicentina, 11: 23–29.

Devictor V., van Swaay C., Brereton T., Brotons L., Chamberlain D., Heliölä J., Herrando S., Julliard R., Kuussaari M., Lindström Å., Reif J., Roy D.B., Schweiger O., Settele J., Stefanescu C., van Strien A., Turnhout C.V., Vermouzek Z., WallisDeVries M., Wynhoff I., Jiguet F. 2012. Differences in the climatic debts of birds and butterflies at a continental scale. Nature Climate Change, 2: 121–124; Doi: 10.1038/nclimate1347

Dieker P., Drees C., Assmann T. 2011. Two high-mountain burnet moth species (Lepidoptera, Zygaenidae) react differently to the global change drivers climate and land-use. Biological Conservation, 144: 2810–2818; Doi:10.1016/j.biocon.2011.07.018

Elith J., Graham C.H., Anderson R.P., Dudík M., Ferrier S., Guisan A., Hijmans R.J., Huettmann F., Leathwick J.R., Lehmann A., Li J., Lohmann L.G., Loiselle B.A., Manion G., Moritz C., Nakamura M., Nakazawa Y., Overton J.M.C., Peterson A.T., Phillips S.J., Richardson K., Scachetti-Pereira R., Schapire R.E., Soberón J., Williams S., Wisz M.S., Zimmermann N.E. 2006. Novel methods improve prediction of species' distributions from occurrence data. Ecography, 21: 129–151; Doi:10.1111/j.2006.0906-7590.04596.x

Elith J., Phillips S.J., Hastie T., Dudík M., Chee Y.E., Yates C.J. 2011. A statistical explanation of MaxEnt for ecologists. Diversity and Distribution, 17: 43–57.

Essl F., Bacher S., Genovesi P., Hulme P.E., Jeschke J.M., Katsanevakis S., Kowarik I., Kühn I., Pyšek P., Rabitsch W., Schindler S., van Kleunen M., Vilà M., Wilson J.R.U., Richardson D.M. 2018. Which taxa are alien? Criteria, applications, and uncertainties. BioScience, 68: 496–509.

Essl F., Dullinger S., Genovesi P., Hulme P.E., Jeschke J.M., Katsanevakis S., Kühn I., Lenzner B., Pauchard A., Pyšek P., Rabitsch W., Richardson D.M., Seebens H., van Kleunen M., van Der Putten W.H., Vilà M., Bacher S. 2019. A conceptual framework for range-expanding species that track human-induced environmental change. BioScience, 69: 908–919; Doi: 10.1093/biosci/biz101

Essl F., Pyšek P., Richardson D.M. 2021. Neonatives and translocated species: different terms are needed for different species categories in conservation policies. NeoBiota, 68: 101–104 DOI: 10.3897/neobiota.68.72849

Fontana P., La Greca M., Kleukers R. 2005. Insecta Orthoptera. Memorie del Museo Civico di Storia Naturale di Verona, Sezione Scienze della Vita, 16: 137–139 + CDrom.

Fourcade Y., Besnard A.G., Secondi J. 2018. Paintings predict the distribution of species, or the challenge of selecting environmental predictors and evaluation statistics. Global Ecology Biogeography, 7: 245–256; Doi: 10.1111/geb.12684

Guisan A., Thuiller W., Zimmermann N.E. 2017. Habitat suitability and distribution models with applications in R (Ecology, Biodiversity and Conservation). Cambridge University Press Doi: 10.1017/9781139028271

Hijmans R.J., Phillips S., Leathwick J., Elith J. 2022. Package 'dismo'. Species Distribution Modelling. Available on-line at https://rspatial.org/raster/sdm/

Hijmans R.J. 2022. Raster: Geographic Data Analysis and Modeling. Available on-line at https://rspatial.org/raster.

Karger D.N., Conrad O., Böhner J., Kawohl T., Kreft H., Soria-Auza R.W., Zimmermann N.E., Linder H.P., Kessler M. 2017. Climatologies at high resolution for the earth's land surface areas. Scientific Data, 4: 170122; Doi: 10.1038/sdata.2017.122

Karger D.N., Conrad O., Böhner J., Kawohl T., Kreft H., Soria-Auza R.W., Zimmermann N.E., Linder H.P., Kessler M. 2021. Climatologies at high resolution for the earth's land surface areas. EnviDat, Doi: 10.16904/envidat.228.v2.1

IPCC. 2014. Annex II: Glossary, pp 117-130. In: Mach KJ, Planton S, von Stechow C (eds.) Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. IPCC, Geneva, Switzerland.

Mason S.C., Palmer G., Fox R., Gillings S., Hill J.K., Thomas C.D., Oliver T.H. 2015. Geographical range margins of many taxonomic groups continue to shift polewards. Biological Journal of the Linnean Society, 115(3): 586–597 Doi: 10.1111/bij.12574

Leandri F., Bardiani M., Battiston R. 2013. Nuova segnalazione di *Ameles spallanzania* (Rossi, 1792) (Insecta, Mantodea) in Pianura Padana. Pianura, 31: 117–120.

Lenoir J., Svenning J.C. 2015. Climate-related range shifts - a global multidimensional synthesis and new research directions. Ecography, 38: 15–28; Doi: 10.1111/ecog.00967

Menéndez R., González-Megías A., Jay-Robert P., Marquéz-Ferrando R. 2014. Climate change and elevational range shifts of dung beetles. Global Ecology and Biogeography, 23: 646–657; Doi: 10.1111/geb.12142

Merow C., Smith M.J., Silander J.A. 2013. A practical guide to MaxEnt for modeling species' distributions: what it does, and why inputs and settings matter. Ecography, 36: 1058–1069.

Parmesan C., Ryrholm N., Stefanescu C., Hill J.K., Thomas C.D., Descimon H., Huntley B., Kaila L., Kullberg J., Tammaru T., Tennet W.J., Thomas J.A., Warren M. 1999. Poleward shifts in geographical ranges of butterfly species associated with regional warming. Nature, 399: 579–583.

Parmesan C., Yohe G. 2003. A globally coherent fingerprint of climate change impacts across natural systems. Nature, 421: 37–42; Doi: 10.1038/nature01286

Payne K. 2017. Observaciones ecológicas sobre dos especies de *Ameles* (Mantodea) en la parte centro-sur de España junto con unas breves notas sobre otros Amelinae en España peninsular. Boletín de la SEA, 60: 347–348.

Pearson R.G., Thuiller W., Araujo M.B., Martinez-Meyer E., Brotons L., McClean C., Miles L., Segurado P., Dawson T.P., Lees D.C. 2006. Model-based uncertainty in species range prediction. Journal of Biogeography, 33: 1704-1711

Peterson A.T., Papeş M., Eaton M. 2007. Transferability and model evaluation in ecological niche modelling: a comparison of GARP and Maxent. Ecography, 30: 550–560; Doi: 10.1111/j.0906-7590.2007.05102.x

Phillips S.J., Anderson R.P., Schapire R.E. 2006. Maximum entropy modelling of species geographic distribution. Ecological Modelling, 190: 231–259; Doi: 10.1016/j.ecolmodel.2005.03.026

Phillips S.J., Dudík M. 2008. Modelling of species distributions with Maxent: new extensions and a comprehensive evaluation. Ecography, 31: 161–175; Doi: 10.1111/j.0906-7590.2008.5203

Potter K.A., Woods A.H., Pincebourde S. 2013. Microclimatic challenges in global change biology. Global Change Biology, 19: 2932–2939.

Pyšek P., Hulme P.E., Simberloff D., Bacher S., Blackburn T.M., Carlton J.T., Dawson W., Essl F., Foxcroft L.C., Genovesi P., Jeschke J.M., Kühn I., Liebhold A.M., Mandrak N.E., Meyerson L.A., Pauchard A., Pergl J., Roy H.E., Seebens H., van Kleunen M., Vilà M., Wingfield M.J., Richardson D.M. 2020. Scientists' warning on invasive alien species. Biological Reviews, 95: 1511–1534; Doi: 10.1111/brv.12627

R Core Team. 2020. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Available on-line at https://www.R-project.org/

Richardson D.M., Pyšek P., Rejmánek M., Barbour M.G., Panetta F.D., West C.J. 2000. Naturalization and invasion of alien plants: concepts and definitions. Diversity and Distributions, 6: 93–107.

Richardson D.M., Pyšek P., Carlton J.T. 2011. A compendium of essential concepts and terminology in biological invasions, pp 409-420. In: Richardson DM (ed) Fifty Years of Invasion Ecology: The Legacy of Charles Elton. Blackwell Publishing, Oxford.

Rödder D., Schmitt T., Gros P., Ulrich W., Habel J.C. 2021. Climate change drives mountain butterflies towards the summits. Scientific Reports, 11: 14382; Doi: 10.1038/s41598-021-93826-0

Schwarz C.J., Ehrmann R. 2018. Invasive Mantodea species in Europe. Articulata, 33: 73–90.

Seneviratne S.I., Lüthi D., Litschi M., Schär C. 2006. Land-atmosphere coupling and climate change in Europe. Nature, 443: 205–209; Doi: 10.1038/nature05095

Suggitt A.J., Gillingham P.K., Hill J.K., Huntley B., Kunin W.E., Roy D.B., Thomas C.D. 2011. Habitat microclimates drive fine-scale variation in extreme temperatures. Oikos, 120(1): 1–8.

Suggitt A.J., Wilson R.J., Isaac N.J.B., Beale C.M., Auffret A.G., August T., Bennie J.J., Crick H.Q.P., Duffield S., Fox F., Hopkins J.J., Macgregor N.A., Morecroft M.D., Walker K.J., Maclean I.M.D. 2018. Extinction risk from climate change is reduced by microclimatic buffering. Nature Climate Change, 8: 713–717; Doi: 10.1038/s41558-018-0231-9

Tabarelli De Fatis K., Debiasi D. 2020. Prime segnalazioni per il Trentino (Italia) di *Ameles spallanzania* (Rossi, 1792) (Dictyoptera: Mantidae). Studi Trentini di Scienze Naturali, 98: 93–95.

Thomas C.D., Ohlemüller R. 2010. Chapter 2: Climate Change and Species' Distributions: An Alien Future?, pp. 19-29. In: Perrings C, Mooney H, Williamson M. (eds) Bioinvasions and Globalization: Ecology, Economics, Management, and Policy. Oxford Academic; Doi: 10.1093/acprof:oso/9780199560158.003.0002

Thuiller W., Georges D., Gueguen M., Engler R., Breiner F. 2021. biomod2: Ensemble Platform for Species Distribution Modeling. Available on-line at https://cran.r-project.org/web/packages/biomod2

Tomozeiu R., Agrillo G., Cacciamani C., Pavan V. 2014. Statistically downscaled climate change projections of surface temperature over Northern Italy for the periods 2021–2050 and 2070–2099. Natural Hazards, 72: 143–168; Doi: 10.1007/s11069-013-0552-y

Tsoar A., Allouche O., Steinitz O., Rotem D., Kadmon R. 2007. A comparative evaluation of presence-only methods for modelling species distribution. Diversity and Distributions, 13: 397–405 Doi: 10.1111/j.14724642.2007.00346.x

Uliana M., Battiston R. 2012. Biodiversità della laguna di Venezia e della costa nord adriatica veneta: Segnalazione n. 216 - *Ameles spallanzania* (Rossi, 1792) (Insecta Mantodea Mantidae). Bollettino del Museo di Storia Naturale di Venezia, 63: 176–179.

Warren D.L., Matzke N.J., Cardillo M., Baumgartner J.B., Beaumont L.J., Turelli M., Glor R.E., Huron N.A., Simões M., Iglesias T.L., Piquet J.C., Dinnage R. 2021. ENMTools 1.0: an R package for comparative ecological biogeography. Ecography, 44: 504–511; Doi: 10.1111/ecog.05485

WMO. 2022. State of the Climate in Europe 2021. World Meteorological Organization (WMO), Switzerland, Geneva, 48 pp.

Wisz M.S., Hijmans R.J., Li J., Peterson A.T., Graham C.H., Guisan A., N.C.E.A.S. Predicting Species Distributions Working Group. 2008. Effects of sample size on the performance of species distribution models. Diversity and Distribution, 14: 763–773; Doi: 10.1111/j.1472-4642.2008.00482.x