European Journal of Ecology, 10.2, 2024, pp. 1-8

THE MEDITERRANEAN-PONTIAN ARGIOPE BRUENNICHI (SCOPOLI, 1772) IN POLAND – OVERVIEW OF TRAITS FAVOURING RANGE EXPANSION

Aldona Dobrzycka-Krahel

Business Faculty, WSB Merito University in Gdańsk, Al. Grunwaldzka 238 A, 80-266 Gdańsk Poland
e-mail:aldona.dobrzycka-krahel@gdansk.merito.pl

Abstract.
Due to climate warming the distribution of Southern European species has extended to the north in recent years. Currently, Argiope bruenichi *(Scopoli, 1772) is distributed over the whole territory of Poland. Data on the current distribution of* A. bruennichi *in Poland and on its occurrence over the years from the GBIF (Global Biodiversity Information Facility) and from the zbioryprzyrodnicze.web.amu.edu.pl database were analysed. Records and habitat preferences by the wasp spider especially in the northernmost parts of Poland were discussed. Observing colonization by the Mediterranean-Pontian species the areas located to the north of the native distributional region provides a unique opportunity to understand traits that facilitate its spreading. The study is also a collection of traits that facilitate range expansion of the wasp spider.*

Key words*:* Argiope bruennichi*, traits, range expansion, Poland*

1. Introduction

Northward movement of Southern European biota is observed for an increasing number of species and may be connected with climate warming (e.g. Dobrzycka-Krahel & Medina-Villar, 2020; Dobrzycka-Krahel et al. 2022; Dobrzycka-Krahel, 2023). In many cases human transport of species is the main reason of its expansion, but spread without initial displacement by human is also observed (Parmesan et al. 1999; Wather et al. 2002) like in this case. The occurrence of *Argiope bruennichi* (Scopoli, 1772) in Poland is the natural course of things, because this species is already found even in countries located in lower latitudes than Poland, e.g. in Scandinavia (e.g. Bratli & Hansen, 2004; Jonsson, 2004).

The wasp spider *A. bruennichi* is a member of the family Araneidae. The family Araneidae belongs to the order Araneae (Foelix, 1982). Araneida is one of the most successful spider families; they have over 3006 species described from 168 genera (Platnick, 2011). A female of *A. bruennichi* is characteristic, easy identified through its vivid coloration, i.e. dorsally with numerous white or yellow transverse stripes, ventrally dark brown with yellow longitudinal stripes and some spots. It is known as species of Mediterranean-Pontian origin (Urbański, 1935, 1948). The species was observed for the first time in Poland in 1874 in Galicia by Nowicki (1874). Later, *A. bruennichi* was noted in the western and south-eastern part of the country (summarised in Barabasz & Górz, 1998). Until 1990s of the 20th century *A. bruennichi* was a rare species in Poland, with distribution records in the western and south-eastern Poland, with occasional occurrences in the eastern part of the country (Bednarz, 1966; Staręga, 1983; Liana, 1993). In the Mazovian Lowland, *A. bruennichi* was observed for the first time in 1998 (Kajak & Łuczak, 2003). At that time, this species was considered to be endangered in Poland, which led to its protection by law. It should be mentioned that at the time the species was almost absent in northern Poland, because of probably harsh climatic conditions (lower temperatures). Only few records of the species were noted in the northern Poland in the 20th century, e.g., its presence in 1948 on the island of Wolin reported by Urbański (1948). The range expansion of the species to the north has been connected with global warming (Krehenwinkel & Tautz, 2013; Krehenwinkel et al. 2015) and started at the beginning of the 21th century. As an effect of climate warming the increased number of dry, sunny days in summer was observed in Poland (Bartoszek et al. 2021). Since then, few papers and notes have been published, in which the increasing spread of the wasp spider in Western Pomerania (Michoński, 2001; Janicki et al. 2006, 2007) and in the north-eastern part of Poland (Wawer & Hajdamowicz, 2018, Wawer et al. 2017) was noted. Despite the limited number of scientific papers on the distribution of the species in Gdańsk Pomerania, there are few press notes. Matwijewicz (2011) reported this species from Człuchów, NIK (2013) from Dobrzęcino near Słupsk and Głowinkowski (2013) from Słupsk. In 2020, Wawer & Wytwer (2020) concluded that the species is distributed over the whole territory of Poland.

Colonization by this Mediterranean-Pontian species the areas located to the north of the native distributional region provides a unique opportunity to observe traits that facilitate its range expansion. Monitoring its habitat and distribution helps in understanding the dynamics of its range expansions. Understanding the specific requirements and the factors that influence the distribution of this

species provides insights into broader ecological processes of this species establishment and helps design effective management strategies.

The aims of this study are: (1) to provide actual data on the distribution of *A. bruennichi* in Poland and especially in the northernmost parts of Poland with habitat preferences by this spider; (2) to discuss features of the species that facilitate its expansion.

2. Materials and Methods

Data on the current distribution of *A. bruennichi* in Poland and on its occurrence over the years were downloaded from the GBIF (Global Biodiversity Information Facility) database on 10.11.2023 and were discussed in the context of traits explaining northward range expansion of the species. Additionally, results from the GBIF database were compared to other observations obtained from the http://zbioryprzyrodnicze.web.amu.edu.pl database (Gierlasiński and Rutkowski, 2023b).

Also the number of observations in the northernmost parts of Poland: on the at least 54 degrees north of the Earth's equatorial plane were determined based on the GBIF database (*Argiope bruennichi* (Scopoli, 1772) in GBIF Secretariat 2023). The results from the GBIF database from northernmost parts Poland were compared to observations obtained from the http://zbioryprzyrodnicze.web.amu.edu.pl database (Gierlasiński and Rutkowski, 2023b).

Local field observations were carried out in August 2023, during sunny days, in Gdynia. Observations were made for 15 minutes at each station. Habitats inhabited by the wasp spiders were observed. Plant species associated with places occupied by the spider were also identified.

3. Results and Discussion

3.1 Distribution Of Argiope Bruennichi (Scopoli, 1772) In Poland

Due to the current data downloaded on 10.11.2023 from GBIF, the Mediterranean-Pontian wasp spider *A. bruennichi* (Fig. 1) is common in different parts of Poland (Fig. 2), including the northern parts of the country. However, this spider is more common (frequent) in the western, south-eastern and central parts of the country than in the northern one. Similar distribution is confirmed by http://zbioryprzyrodnicze.web.amu.edu.pl database (Gierlasiński and Rutkowski, 2023b). On the basis of available data it is known that this spider's occurrence in Poland is in: Beskid Wschodni, Beskid Zachodni, Bieszczady, Galicja, Góry Świętokrzyskie, Nizina Mazowiecka, Nizina Sandomierska, Nizina Wielkopolsko-Kujawska, Pobrzeże Bałtyku, Podlasie, Pojezierze Mazurskie, Pojezierze Pomorskie, Puszcza Białowieska, Roztocze, Sudety Wschodnie, Sudety Zachodnie, Ślask Dolny, Śląsk Górny, Wyżyna Krakowsko-Wieluńska, Wyżyna Lubelska, Wyżyna Małopolska, Wzgórza Trzebnickie.

It is worth mention that in some regions in Poland this taxon has not been recorded, most probably because of insufficient investigations. It is also likely that large areas of the country are forested, which is not conducive to the occurrence of this species. Changes in land use, such as the creation of open, sunny habitats through agriculture or deforestation, could facilitate the spread of this spider (Barabasz and Górz, 1998). The eastern part of Poland limit expansion of the species, because can have lower temperatures compared to the country's western and central parts, and might not consistently offer the warm conditions preferred by the spider. The active and breeding season length is critical for the survival of species with annual life cycles like *A. bruennichi*. In eastern Poland, a shorter warm season could limit the spider's ability to complete its life cycle from mating to laying eggs and the emergence of new spiders. Harsh winters are particularly challenging for *A. bruennichi*, as it typically does not survive the cold season in adult form. Instead, it overwinters as eggs, and the survival of these eggs can be jeopardized by extremely low temperatures or fluctuating winter conditions that may lead to egg mortality.

Figure 1. *Argiope bruennichi* (Scopoli, 1772) female: A/ lateral, B/ dorsal, C/ ventral side (Photo: Grażyna Dobrzycka)

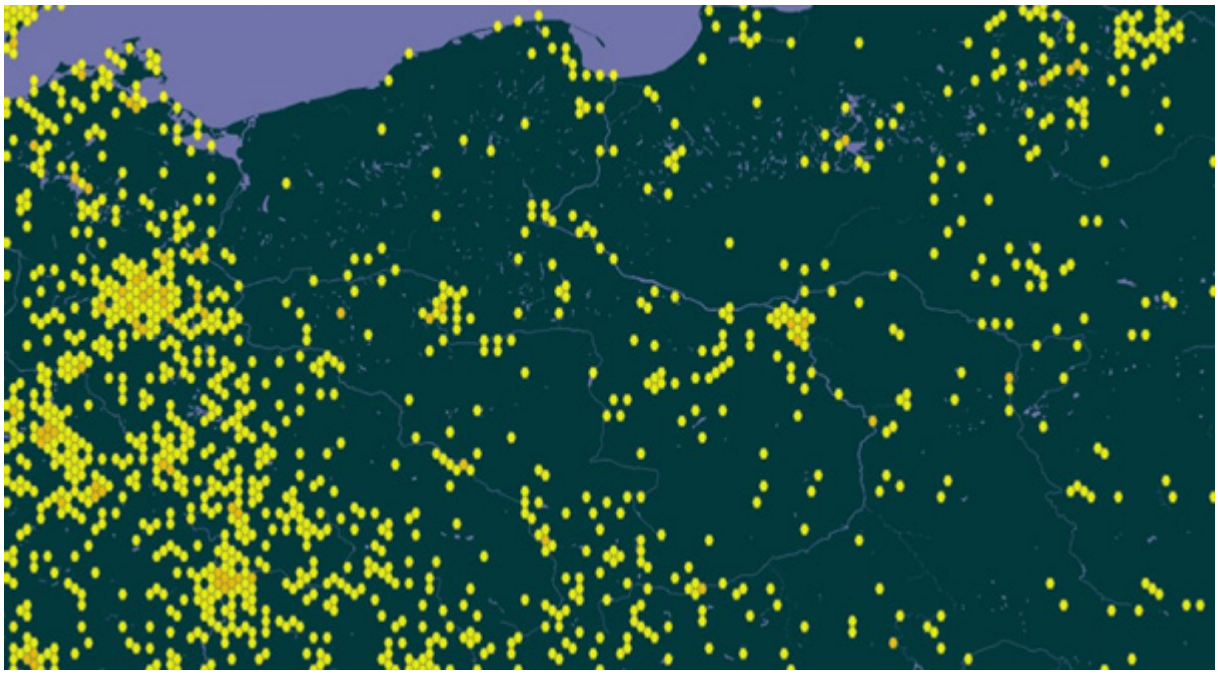

Figure 2. *Argiope bruennichi* (Scopoli, 1772) distribution map in Poland (based on: *Argiope bruennichi* (Scopoli, 1772) in GBIF Secretariat 2023)

3.1.1 Distribution Of Argiope Bruennichi (Scopoli, 1772) In The Northernmost Parts Of Poland

The number of observations of *A. bruennichi* in northern Poland in the 21th century on the at least 54 degree of the northern geographical latitude is relatively low (20 observations) in the GBIF database (Figs.2 and 4). Due to the GBIF database the species was noted for the first time in the northernmost parts of Poland in 2006 (1 observation) and the highest number of observations (11 observations) was recorded in 2021 (Fig.4). The observation from 2006 confirmed its occurrence in Western Pomerania and the observation from 2010 confirmed its occurrence in the north-eastern part of Poland (in Mazury Lake District). The species was also found in Wdzydze near Kościerzyna (Gdańsk Pomerania) in 2019, and in Odargowo close to the Baltic Sea in 2021. Specimens of *A. bruennichi* were observed near Tricity in 2021.

For comparison, there are only 13 observations from the Baltic coast (Poland) recorded in the 20th and 21th century in another database: http://zbioryprzyrodnicze.web.amu.edu.pl (Gierlasiński and Rutkowski, 2023b): in Chomino (Janicki et al. 2006), Dębki (Gierlasiński et al. 2022b), Gogolice (Gierlasiński et al. 2022b), Kołczewo (Gierlasiński and Rutkowski, 2023b), Ładzin (Gierlasiński and Rutkowski, 2023b), Myślibórz Mały (Janicki et al. 2006), Niemica (Janicki et al. 2006), Objazda (Gierlasiński et al. 2022b), Płocin (Gierlasiński and Rutkowski, 2023b), rez. Warnie Bagno (Gierlasiński et al. 2022b), Świnoujście, (Wawer et al. 2017), Tyłowo (Gierlasiński et al. 2022b), Warnowo (Gierlasiński and Rutkowski 2023b), and Wolin (wyspa) (Urbański, 1948, Rafalski, 1953, Czajka, 1957, Dziabaszewski, 1965, Barabasz and Górz,, 1998). However, many of these observations were localized on higher than 54 degree northern geographical latitude.

A total of 21 adult females of the wasp spider *A. bruennichi* were found during field observations in Gdynia in August 2023 (Table 1). Specimens of *A. bruennichi* were observed at 10 sites. These field observations confirm occurrence of the spider in Tricity/Gdańsk Pomerania. The spiders were on their webs with characteristic species-specific stabilimentum. Their occurrences were connected with different plant species (Table 1). The spiders were observed in sunny areas, densely overgrown with high plants (mainly grass). All stations were in the areas associated with human activity. More spiders (8 specimens) were noted in the garden (the silent, safe place) than at places located at the edges of forests, at roads (from 1 to 2 specimens per station), exposed to human and animal (e.g. dogs, cats and/or wild boars) pressure. Only females were among the observed specimens.

Table 1. Observed habitats of the wasp spider *Argiope bruennichi* (Scopoli, 1772) during field studies in August 2023 in Gdynia (own study)

Number of site	Data	Habitat	Plants on the station
1	19.08.2023	garden	*Medicago sativa, Plantago lanceolate, Lolium perenne, Festuca arundinacea, Poa pratensis, Dactylis glomerata, Convolvulus arvensis*
2	22.08.2023	dry meadow at the edge of forest, at the road	*Festuca arundinacea, Artemisia vulgaris, Convolvulus arvensis*
3	22.08.2023	dry meadow at the edge of forest, at the road	*Festuca arundinacea,Artemisia vulgaris, Convolvulus arvensis*
4	22.08.2023	dry meadow at the edge of forest, at the road	*Festuca arundinacea, Artemisia vulgaris, Convolvulus arvensis, Polygonum aviculare, Plantago major, Achillea millefolium, Hordeum murinum*
5	23.08.2023	dry meadow at the road	*Lolium perenne, Festuca arundinacea, Artemisia vulgaris, Convolvulus arvensis, Diplotaxis tenuifolia*
6	24.08.2023	dry meadow at the road	*Lolium perenne, Festuca arundinacea, Artemisia vulgaris, Convolvulus arvensis, Polygonum aviculare, Plantago major, Achillea millefolium, Hordeum murinum*
7	25.08.2023	dry meadow at the road	*Lolium perenne, Diplotaxis tenuifolia, Equisetum arvense L., Plantago lanceolate*
8	25.08.2023	dry meadow at the road	*Lolium perenne,Plantago lanceolate*
9	25.08.2023	meadow at the edge of forest, at the road	*Lolium perenne, Diplotaxis tenuifolia, Crepis capilaris*
10	25.08.2023	dry meadow at the edge of forest, at the road	*Lolium perenne, Plantago lanceolate, Erigeron canadensis, Trifolium L.*

Table 2. Reported habitats of the wasp spider *A.bruennichi* in the Baltic coast (Poland)

Location	Data	Habitat	Source
Dębki	13-14.07.2020	low herbaceous vegetation along the beach	Gierlasiński et al. 2022
Objazda	6.08.-7.09.2014	xerothermic turf	Gierlasiński et al. 2022
Tyłowo	12.09.2020	edge of mixed forest	Gierlasiński et al. 2022
Ładzin	4.08.2021	railway embankment	Gierlasiński and Rutkowski 2023a
Płocin	2.08.2021	dry meadow	Gierlasiński and Rutkowski 2023a
Warnowo	4.08.2021	railway embankment	Gierlasiński and Rutkowski 2023a

3.2. Traits Of *Argiope Bruennichi* (Scopoli, 1772)

A. bruennichi is considered the most interesting spider species in Poland. On the one hand, the species lives in variable habitats, it is a generalist regarding inhabited environments and many studies provide evidence for a high plasticity of this species in terms of habitat selection (Żurawlew, 2010). Habitat plays an important role in the life style of this species (Szymkowiak et al. 2005). It is a thermophilous wasp spider, so warmer conditions may be important for its spreading and growth. In fact, *A. bruennichi* is a thermophilic and heliophilic species. Now it is the one of the most numerous spiders occurring in non-forest ecosystems (Wawer and Mróz, 2006). It occupies most often open spaces: meadows, less often dry, xerothermic slopes, grassy edges of pine groves or fences (e.g. Bednorz, 1996; Barabasz & Górz, 1998). The presence of this species is often observed in habitats with high plants (mainly grasses), where it builds flexible, vertical orb web at a height of about 20-50 cm between the stems of plants (Table 1). In the centre of the orb web there is a so-called stabilimentum - zigzag thread reinforcing the structure of the web (Kowalczyk, 1997). Individuals of this species also occurs in railway embankment (Gierlasiński and Rutkowski, 2023), and can occur even in the mountains, where climatic conditions are harsh (Wawer, 2021). The species has been found on the banks of ditches, watercourses, small rivers, ponds, peat bogs, clay pits, on meadows of varying humidity and in gravel pits. Among the buildings, females on orb webs were found among shrubby conifers, on the juniper *Juniperus sabina* and cy-

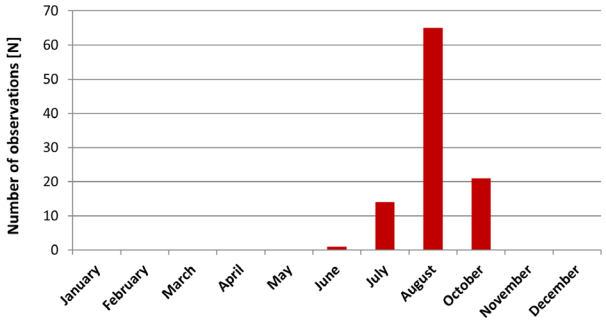

Figure 3. The number of observations of *Argiope bruennichi* (Scopoli, 1772) in Poland over 2022 (based on *Argiope bruennichi* (Scopoli, 1772) in GBIF Secretariat 2023)

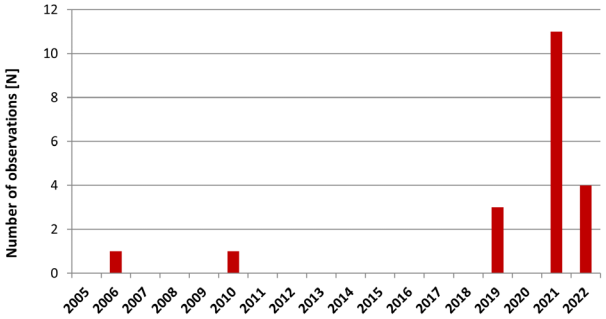

Figure 4. The number of observations of *Argiope bruennichi* (Scopoli, 1772) on the at least 54 degree of the northern geographical latitude in Poland in the 21th century, (based on *Argiope bruennichi* (Scopoli, 1772) in GBIF Secretariat 2023)

press Chamaecyparis sp., in addition, on the ivy vine Parthenocissus sp. growing on the building, and even on the abandoned concrete circle of the well. It was found also in the cornfield of *Zea mays* (Żurawlew, 2010). Additionally, in the Baltic coast (Poland) this species was observed in habitats characteristic for coastal areas: low herbaceous vegetation along the beaches (new habitat) (Gierlasiński et al. 2022, Table 2). In such places, it may be exposed to threats from tourists.

Females (2.0–2.5 cm) are much larger than males (0.8–1.2 cm) (Kim et al. 2012).The species is well adapted to capture large prey, has potential to capture more food than other spiders thanks to specific construction of web with characteristic stabilimenta. Previous study regarding values of spiders' webs reported that webs with stabilimenta capture more large prey than webs without stabilimenta (Kim et al. 2012). Moreover, bright coloration of wasp spider attracts insect prey (Bush et al. 2008). Many insects are attracted to colours of flowers and the predator could take advantage of coloration. Bright coloration act as a sensory trap, mimicking signals for prey. Therefore, prey consists of jumping or flying arthropods such as Coleoptera, Diptera, Homoptera, Heteroptera, Hymenoptera, Lepidoptera, Mecoptera, Odonata, Orthoptera and Neuroptera (Szymkowiak et al. 2006). The spider is a generalist predator of herbivores being a consumer in herbivore communities of grassland food webs (Taraschewski et al. 2005). It was also observed ingestion of a small specimen of the common frog (vertebrate) by *A.bruennichi*, confirming that this species is ecologically flexible in the use of novel food sources and this adaptation probably allows the colonisation of new localities, as well as habitats (Szymkowiak et al. 2006).

The reproductive success of this species depends on many factors. Interestingly, females of this species produce a large, urn shaped egg sac, positioned in the higher levels of vegetation, and in which offspring pass the winter after having hatched from the eggs, ready to spread next spring after emergence from the egg sac (Terhivuo et al. 2011). Reproduction of this species is usually characterised by large clutch size. Females of *A. bruennichi* produce up to five egg sacs in the field, often containing several hundred eggs (Crome & Crome, 1961; Köhler & Schäller, 1987). Production of egg sacs may be considered as adaptation strategy of a species to harsh climatic conditions: low temperatures and frost (Dobrzycka-Krahel et al. 2022), it helps in overwintering and hibernation of eggs. In Poland, specimens of this species are usually observed in mating season from June to October (Fig. 3). Females construct an egg sac near their web, which is above the ground, attached to grass. They stay on the egg sac for a few days and then eggs start developing immediately. Clutch size is linked to spider body condition and food availability, but not the time of oviposition (Leborgne & Pasquet, 2005).

The lack of males is often observed in populations of *A. bruennichi*, if populations are inspected late in the season. In fact, males die after copulation or become eaten by the cannibalistic *A. bruennichi* females (Fromhage et al. 2003). Moreover, Bratli & Hansen (2004), Almquist (2005), Spuņģis (2005) and Terhivuo et al. (2011) showed that only females of *A. bruennichi* were recorded in areas, where the species has not yet become permanently established.

Aeronautic behaviour known as aerial dispersal (ballooning) predisposes the species to fast colonization of vast areas (Follner & Klarenberg, 1995). Juveniles travel by floating on individual threads of webs, drawn from the back of the abdomen. Thanks to wind, they are able to disperse over very long distances. Such dispersal strategy facilitates range expansion. However, ballooning is limited to young stages, the adult females are relatively stationary, because of their body size and weight do not disperse by air (Crome & Crome, 1961).

Based on described features of A. *bruennichi* it is possible to state that these traits facilitate expansion. Howev-

er, agrotechnical practices: lawns moving and haymaking may cause disappearance of habitats for the species (as the spider prefers relatively high plants/grasses) and may destroy cocoons, which should successfully overwinter. Also intensification of urbanisation may effect on occurrence of this species. The destruction of natural habitats of this spider may lead to a species decline. Tourist activity in places of new records of this species (e.g., in coastal areas) may pose a threat. Thus, human activity may disturb spread of this species as well as cause its extermination.

4. Conclusions

Argiope bruennichi is distributed over the whole territory of Poland thanks to adaptations that predispose this species to range expansion, e.g., plasticity in terms of environment, behaviour and rapid reproduction. It faces habitat loss due to presence in the areas associated with human activity, on sites exposed to human and animal pressure, tourists activity, and on places with agricultural expansion and urbanization. Monitoring the distribution and habitats occupied by *A. bruennichi* is crucial for prediction management strategies. Regular surveys should be conducted to assess potential threats such as habitat destruction. As climate change may alter the distribution and reproductive patterns of *A. bruennichi*, adaptive management strategies should be developed. This might include studying migration patterns and changes in habitat usage due to shifting climate zones, as well as predicting future distributions under various climate scenarios. Educational programs that highlight the role of spiders in biodiversity and ecosystem health can help reduce misplaced fears and encourage conservation-minded landscaping and agricultural practices. The management of *A. bruennichi* should be multifaceted, incorporating ecological, agricultural, and community-based approaches. Policy measures could include incentives for farmers who adopt spider-friendly practices and restrictions on the use of harmful pesticides or lawns moving and haymaking in areas known to be important for this and other beneficial species. By promoting its conservation and beneficial role in ecosystems (insects consuming), particularly in agricultural pest management, *A. bruennichi* can be preserved as a valuable part of natural biodiversity while also contributing to sustainable agricultural practices and sustainable human behaviour in relation to the wasp spider.

References

Argiope bruennichi (Scopoli, 1772) in GBIF Secretariat (2023) GBIF Backbone Taxonomy. Checklist dataset https://doi.org/10.15468/39omei accessed via GBIF.org on 2023.11.10.

Almquist, S. (2005) Swedish Araneae, part 1 – families Atypidae to Hahniidae (Linyphiidae excluded). Insect Systematics and Evolution, Supplement 62: 1–2.

Barabasz, B., & Górz, A. (1998) *Argiope bruennichi* (Scopoli, 1772) - rzadki i słabo zbadany gatunek pająka w Polsce. Fragmenta Faunistica, 41(20): 255-261.

Bartoszek, K., Matuszko, D. & Węglarczyk, S. (2021) Trends in sunshine duration in Poland (1971–2018). International Journal of Climatology, 41: 73–91. https://doi.org/10.1002/joc.6609.

Bednarz, S. (1966) Nowe stanowiska tygrzyka paskowanego, *Argiope bruennichi* Scop. (Ariopidae) w Polsce na Dolnym Śląsku. Przegląd Zoologiczny, 10: 179-185.

Bratli, H. & Hansen, L.O. (2004) The wasp spider *Argiope bruennichi* (Scopoli, 1772) Aranea, Araneidae) observed in Norway. Norwegian Journal of Entomology, 51.

Bush, A.A., Yu, D.W. & Herberstein, M.E. (2008) Function of bright coloration in the wasp spider *Argiope bruennichi* (Aranea: Araneidae). Proc Biol Sci 7: 275(1649): 1337-1342. https://doi.org. 10.1098/rspb.2008.0062.

Crome, W. & Crome, I. (1961) Paarung und Eiablage bei *Argyope bruennichi* (Scopoli) auf Grund von Freilandbeobachtungen an zwei Populationen im Spreewald/Mark Brandenburg (Araneae: Araneidae). Mitteilungen aus dem Zoologischen Museum in Berlin 37:189–252.

Czajka M. (1957) Kilka nowych stanowisk dwóch rzadkich pająków w Polsce. Przegląd Zoologiczny, 1: 178–179.

David, I.J. & Dufresne, F. (2021) 'Parthenogenesis', in Rickey Cothran, and Martin Thiel (eds), Reproductive Biology: The Natural History of the Crustacea, Volume 6 (New York, 2020; online edn, Oxford Academic, 2021), https://doi.org/10.1093/oso/9780190688554.003.0009.

Dobrzycka-Krahel, A. & Medina-Villar, S. (2020) Alien species of Mediterranean origin in the Baltic Sea Region: current state and risk assessment. Environmental Reviews, 28(3): 339-356. https://doi.org/10.1139/er-2019-0074.

Dobrzycka-Krahel, A., Lynn Kemp, J. & Fidalgo, M.L. (2022) Cold-tolerant traits that favour northwards movement and establishment of Mediterranean and Ponto-Caspian aquatic invertebrates. Aquatic Sciences, 84(4): 47. https://doi.org/10.1007/s00027-022-00879-y.

Dobrzycka-Krahel, A. (2023) Movement of Southern European aquatic alien invertebrate species to the north and south. Water, 15: 2598. https://doi.org/10.3390/w15142598.

Dziabaszewski A. (1965) Pająki wyspy Wolin ze szczególnym uwzględnieniem Wolińskiego Parku Narodowego. Część I. Prace Komisji Biologicznej Poznańskiego Towarzystwa Przyjaciół Nauk, 31: 33–131.

Follner, K. & Klarenberg, A.J. (1995) Aeronautic behavious in the wasp-like spider, *Argiope bruennichi* (Scopoli) (Aranea, Argiopidae). Proceedings of the 15th European Colloquium of Arachnology. Edited by V. Ruzicka. Institute of Entomology, Ceske Budejovice: 66-72.

Fromhage, L., Uhl, G. & Schneider, J. M. (2003) Fitness consequences of sexual cannibalism in female *Argiope bruennichi*. Behavioral Ecology and Sociobiology, 55 (1): 60-64.

Gierlasiński G., Kowalczyk J.K.&Rutkowski T. (2022) Nowe dane o rozmieszczeniu pająków (Araneae) na Pobrzeżu Bałtyku. Rocznik Muzeum Górnośląskiego w Bytomiu.Przyroda, 28(online 011): 1–21.

Gierlasiński G., Rutkowski T. (2023) Pająki (Araneae) wyspy Wolin. Rocznik Muzeum Górnośląskiego w Bytomiu. Przyroda 29 (online 009): 1–25.

Gierlasiński G.& Rutkowski T. (2023b) Pająki (Araneae) Polski. http://zbioryprzyrodnicze.web.amu.edu.pl, dostęp: (3.05.2024).

Głowinkowski, K. (2011) Jadowity pająk w centrum Słupska! Głos Pomorza. GP24. https://gp24.pl .Access: 22.08.2023.

Gruber, J. (1990) Fatherless spiders. British Arachnology Society Newsletter, 58: 3.

Janicki, D., Zawal, A., Dąbkowski, P. & Zyska, W. (2006) Występowanie *Argiope bruennichi* Scopoli, 1772 [Aranei] na Pomorzu Zachodnim. Occurrence of *Argiope bruennichi* Scopoli, 1772 [Aranei] on Western Pomerania Zeszyty Naukowe. Acta Biologica, 15. Uniwersytet Szczeciński: 115-121.

Janicki, J.J., Kartowska, W., Konopska, K. & Grudzień, A. (2007) Występowanie tygrzyska paskowanego *Argiope bruennichi* (Scopolli, 1772 Aranei) w rezerwacie przyrody Świdwie. Biology.

Jonsson, L.J. (2004) The wasp spider, *Argiope bruennichi*, established in and spreading north in Sweden. Entomologisk Tidsfrift 125(3): 117-120.

Kajak, A. & Łuczak, J. (2003) Pajaki – znaczenie, liczebność, skład, rozmieszczenie przestrzenne. Pp. 533–538. In Kampinoski Park Narodowy. Przyroda Kampinoskiego Parku Narodowego. (R. Andrzejewski, ed.). Kampinoski Park Narodowy, Izabelin.

Kim, K.W., Kim, K. & Choe, J.C. (2012) Functional values of stabilimenta in a wasp spider, *Argiope bruennichi*: support for the prey-attraction hypothesis. Behav Ecol Sociobiol 66: 1569–1576. https://doi.org/10.1007/s00265-012-1410-8.

Köhler, G. & Schäller, G. (1987) Untersuchungen zur Phänologie und Dormanz der Wespenspinne *Argiope bruennichi* (Scopoli) (Araneae: Araneidae). Zoologisches Jahrbuch für Systematik 114: 65–82.

Korenko, S., Smerda, J. & Pekar, S. (2009) Life-history of the parthenogenetic oonopid spider, *Triaeris stenaspis* (Araneae: Oonopidae). European Journal of Entomology, 2009, 106(2): 217–223.

Kowalczyk, J.K. (1997) Tygrzyk paskowany *Argiope bruennichi* na Mazowszu. Wszechświat, 12: 312.

Krehenwinkel, H. & Tautz, D. (2013) Northern range expansion of European populations of the wasp spider *Argiope bruennichi* is associated with global warming-correlated genetic admixture and population-specific temperature adaptations. Molecular Ecology, 226(8): 2232-48. https://doi.org/10.1111/mec.12223.

Krehenwinkel, H., Rödder, D. & Tautz, D. (2015) Eco-genomic analysis of the poleward range expansion of the wasp spider *Argiope bruennichi* shows rapid adaptation and genomic admixture. Global Change Biology, 21: 4320-4332. https://doi.org/10.1111/gcb.13042.

Leborgne, R. & Pasquet, A. (2005) Time of oviposition and reproductive success in *Argiope bruennichi* (Araneae: Araneidae). Eur. J. Entomol. 102: 169-174.

Liana, A. (1993) Występowanie rzadkiego pająka – tygrzyka *Argiope bruennichi* na Roztoczu. Chrońmy Przyrodę Ojczystą, 49, 2: 49-53.

Matwijewicz, T. (2011) Człuchów: Jadowity pająk wypoczywa na Pomorzu. Głos Pomorza. GP24.pl. https://gp24.pl/. access: 22.08.2023.

Michoński, G. (2001) Tygrzyk paskowany *Argiope bruennichi* (Scopoli, 1772) w Ińskim Parku Krajobrazowym (Pomorze Zachodnie). Przegląd Przyrodniczy, 12, 1-2: 150-151.

Nentwig, W., Blick, T., et al. (2021) Spiders of Europe. Online at https://araneae.nmbe.ch/, accessed on 19.08.2023.

NIK, (2013) Czytelnik przestraszył się paskowanego pająka. Głos Pomorza. GP24. https://gp24.pl . Access: 22.08.2023.

Nowicki, M. (1874) Dodatek do fauny pajęczaków Galicyi. Sprawozdanie Komitetu Fizjograficznego, Kraków 8 (1): 11.

Parmesan, C., Ryrhalan, N., Stefenson, C., Hill, J.K., Thomas, C.D., Descinan, H., Huntley, B., Kaila, L., Kullberg, J., Tommarn, T., Tennen, W.J., Thomos, J. & Warren, M. (1999) Poleward shifts in geographical ranges of butterfly species associated with regional warming. Nature, 399: 579-583.

Platnick, N.I. (2012) The World Spider Catalog, Version 12.5. American Museum of Natural History. Online at http://research.amnh.org/iz/spiders/catalog, accessed on 28.02.2022.

Rafalski J. (1953) Fauna pajęczaków Parku Narodowego na Wyspie Wolinie w świetle dotychczasowych badań. Ochrona przyrody, 21: 217–248.

Spuņģis, V. (2005) Wasp spider *Argiope bruennichi* (Scopoli, 1772) (Aranea, Araneidae) in Latvia. Latvijas Entomologos 42: 86.

Staręga, W. (1983) Wykaz krytyczny pająków (Aranei) w Polsce. Fragmenta Faunistica. Warszawa 27: 149-268.

Szymkowiak, P. S., Tryjanowski, P., Winiecki, A., Grobelny, S., & Konwerski, S. (2005) Habitat differences in the food composition of the wasp-like spider *Argiope bruennichi* (Scop.)(Aranei: Araneidae) in Poland. Belgian Journal of Zoology, 135.

Taraschewski, C., Sanders, D., Nickel, H. & Platner, C. (2005) Effects of the wasp-spider, *Argiope bruennichi,* on planthoppers and leafhoppers. Beiträge zur Zikadenkunde 8: 49-58.

Terhivuo, J., Fritzen, N.R. & Pajunen, T. (2011) Increased number of observations and notes of offspring production in the invasive orb-web spider *Argiope bruennichi* (Scopoli, 1772)(Aranea; Araneidae) in Finland. Memoranda Societatis pro Fauna et Flora Fennica, 87: 95-101.

Urbański, J. (1935) Pająk *Argyope bruennichi* Scop. w Ludwikowie. Wydawnictwo Okręgowego Komitetu Ochrony Przyrody na Wielkopolskę i Pomorze, 5: 134-136.

Urbański, J. (1948) *Argyope bruennichi* (Scopoli) 1772 na wyspie Wolin oraz rozmieszczenie tego gatunku na ziemiach polskich. Badania fizjograficzne nad Polską zachodnią. Poznań 1: 160-169.

Walther, G.R., Post, E., Conney, P., Menzol, A., Parmesan, C., Beenbee, T.J.C., Fromentin, J.M., Hoeghl-Gulberg, O. & Barlein, F. (2002) Ecological responses to recent climate change. Nature, 416: 389-395.

Wawer, W. & Mróz, I. (2006) Występowanie tygrzyka paskowanego *Argiope bruennichi* w zbiorowiskach roślinności niskiej Kampinoskiego Parku Narodowego. Parki Narodowe i Rezerwaty Przyrody. National Parks and Nature Reserves 25(4): 61-70.

Wawer, W. (2012) Notes on the occurrence of the expansive spider *Argiope bruennichi* and others orb-weaver spiders in the Beskids Mountains. Nowy Pam. Fizjogr., Warszawa, 7 (1–2): 45–51.

Wawer, W., Rutkowski, R., Krehenwinkel, H., Lutyk, D., Pusz-Bocheńska, K. & Bogdanowicz, W. (2017) Population structure of the expansive wasp spider (*Argiope bruenmchi*) at the edge of its range. The Journal of Arachnology 45 (3): 361-369.

Wawer, W. & Hajdamowicz, I. (2018) Spatial niche separation on the periphery range of *Argiope bruennichi* andIts eEffect with *Araneus quadratus* (Araneae: Araneidae). Environmental Entomology, 47(1): 26–31. https// doi.org/10.1093/ee/nvx173.

Wawer, W. & Wytwer, J. (2020) Abundance changes in orb-weaver spider communities at the edge of the *Argiope bruennichi* expansion range. Zootaxa 4899 (1): 363−373.https:// doi.org/10.11646/zootaxa.4899.1.18.

Żurawlew P. (2010) Występowanie tygrzyka paskowanego *Argiope bruennichi* (Scopoli, 1772) w powiecie pleszewskim (Wielkopolska). Kulon 15 (2010): 85-87.