https://www.biodiversityjournal.com - Edizioni Danaus
Biodiversity Journal, 2025, 16 (1): 3–6 - **Article**
https://doi.org/10.31396/Biodiv.Jour.2025.16.1.3.6

Biodiversity Journal
ISSN 2039-0394 (Print Edition)
ISSN 2039-0408 (Online Edition)

Time to freezing: plasticity or rapid evolution. A preliminary study

Ayari Nakaka[1] & Kazuki Kimura[2,*]

[1]Faculty of Sciences, Tohoku University, Kawauchi 41, Aoba-ku, Sendai, 980-0862 Japan
[2]Center for Northeast Asian Studies, Tohoku University, Kawauchi 41, Aoba-ku, Sendai, 980-0862 Japan
[*]Corresponding author, e-mail: k.kimura.000@gmail.com, ORCID: 0000-0003-1091-2313

ABSTRACT The orb-weaving spider *Trichonephila clavata* (L. Koch, 1878) (Araneae Nephilidae), commonly known as Joro spider, was recently introduced into North America and has been spreading in the invaded territory. Several studies have suggested potential negative impacts of this spider on native communities. The present study focused on risk-taking behavior in Joro spider individuals from their native range. A comparison between our behavioral experiment and a previous study investigating an exotic population in the USA suggests that spiders tend to exhibit more risk-aversive behavior in the introduced region. Although it remains unclear whether the observed difference is an adaptive or plastic change, knowledge on the adaptability of Joro spiders to novel conditions is crucial for assessing their impact on the ecosystem.

KEY WORDS Conservation; exotic species; spider; risk-aversion; *Trichonephila clavata.*

Received 24.10.2024; accepted 21.12.2024; published online 21.02.2025

INTRODUCTION

The impact of invasive species on native species, communities, and ecosystems is now widely recognized (Lodge, 1993; Sala et al., 2000). Moreover, invasive species can cause severe negative effects on human health and the economy (Chinchio et al., 2020; Angulo et al., 2022). Numerous cases of rapid evolution in invasive species in response to novel environmental and ecological conditions have been documented (e.g., Phillips et al., 2006; Lankau et al., 2009). Such rapid evolution can lead to the range expansion of invasive species in their new environment, increasing the difficulty of their eradication and the mitigation of their ecological and economic impacts (Prentis et al., 2008). Understanding the potential for adaptive changes in invading species is important for conservation management.

The orb-weaving spider *Trichonephila clavata* (L. Koch, 1878) (Fig. 1), commonly known as Joro spider, is native to East Asian countries such as Japan and China (Pan et al., 2016; Suzuki & Asano, 2022). This spider was recently introduced into North America likely through the transport of shipping containers, and it has spread over approximately 120,000 km^2 within about 10 years of its introduction (Hoebeke et al., 2015; Chuang et al., 2023). Moreover, the suitable climatic habitat for *T. clavata* was estimated to cover the entire area of the USA (Giulian et al., 2024). This exotic spider was found to prey on a variety of arthropod species and build webs in environments similar to those of several native spiders in the USA (Chuang et al.,

2023; Grabarczyk et al., 2023). The number of native orb-weaving spider species was lower in areas where a Joro spider population had established earlier (Nelsen et al., 2023). These findings suggest potential negative impacts on the native community.

Freezing behavior, in which an individual remains immobile in the same position after receiving a physical stimulus, is known to occur across a wide range of animal taxa, including spiders, and is often discussed in the context of anti-predator strategies (Humphreys & Ruxton, 2018). Freezing in Joro spiders was reported for individuals from the exotic population in North America (Davis & Anerao, 2023). Interestingly, the duration of their freezing behavior was exceedingly longer than that of many other spider species, which could lead to a high survival rate against predator attacks. However, freezing behavior in native populations of Joro spiders remains unexamined, and the prolonged freezing may be an adaptive consequence occurred in the introduced region. Here we examined freezing behavior of Joro spiders in their native range and discussed this possibility of adaptation.

MATERIAL AND METHODS

Our aim was to compare the results reported by Davis & Anerao (2023) with ours, and therefore we followed their experimental procedures. Adult female individuals of Joro spiders (n = 20) were collected during the fall (October and November 2023) in Sendai, Japan, which is within the native range of the spider. Individuals from colonial webs were not selected because the influence of web type (colonial vs. solitary) on risk-taking behavior in Joro spiders remains unresolved. After collection, each spider was placed in a separate 50 mL centrifuge tube and held at 10 ℃ overnight. The individuals were transferred to an experimental room and acclimated to room temperature (approximately 22 ℃) for 1 hour before the trials of freezing experiment.

Each individual was gently transferred from the centrifuge tube into an empty white plastic container (40 cm × 28 cm × 15 cm) and allowed 1 min to explore the container. The individual was exposed to two rapid puffs of air from a distance of about 5 cm in front of it using a 20 cm long turkey baster. All spiders exhibited freezing behavior when they were blown, and the durations of freezing were recorded. To compare the difference between our result for the native population and the previous result for the exotic population, the Hedges' d effect size and 95% confidence interval were calculated using the R package 'metafor' (Viechtbauer, 2010) in R-4.1.1 (R Core Team, 2021). This effect size estimate corrects for bias associated with small sample sizes (Hedges, 1981). Significance of the effect size was determined by whether the 95% CI overlapped with zero.

RESULTS AND DISCUSSION

The Joro spiders from Japan exhibited shorter freezing behavior than those from the exotic population (Fig. 2). The effect size of the difference between these populations was 1.28 (95% CI: 0.41–2.14), indicating a significant difference. Although our experiment only treated the Japanese population of Joro spiders and the invasion of Joro spiders into the USA may have been from an Asian country other than Japan, little genetic difference was documented among individuals from Asian countries (Japan and China) and the USA (Hoebeke et al., 2015). This genetic close relationship is considered to reflect the orb-weaving spiders' habit of ballooning dispersal, which likely results in little genetic structure across their distribution range in Asia (Bell et al., 2005; Lee et al., 2015). Therefore, the observed difference in freezing behavior is unlikely to be attributable to differences existing between the origin-population of the Joro spiders in the USA and the Japanese population. Alternatively, the longer freezing in the exotic population can be explained by plasticity or rapid evolution. Environmental and ecological factors, such as temperature, food availability and predation risk, are known to affect antipredator behavior and risk-taking in spiders (Cobb, 1994; Walker & Rypstra, 2003; Bell et al., 2006). For example, the composition or density of predators is likely to differ between the study areas in this and previous studies (i.e., between Sendai, Japan and Georgia). The Joro spiders from the USA population may have experienced more frequent predatory attacks before capture, resulting in

Figure 1. The orb-weaving spider *Trichonephila clavata* (L. Koch, 1878).

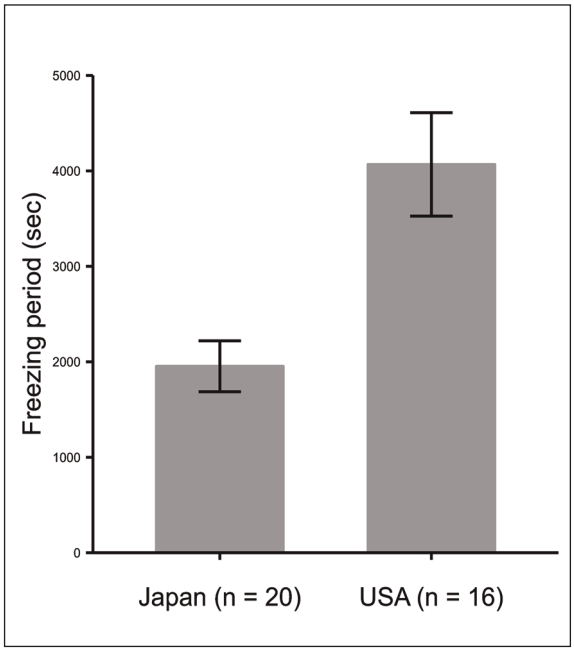

Figure 2. Mean duration (± SE) of freezing behavior in Joro spiders.

improvement in antipredator behavior. Alternatively, strong predation pressure may have favored spider individuals with prolonged freezing behavior in the USA. Further experiments are needed to clarify whether the behavioral difference between the native and exotic populations is an adaptive or plastic change. The distribution range of Joro spiders continues to expand in North America (Hoebeke et al., 2015; Chuang et al., 2023), and the first record from the Russian Far East in 2023 suggests that range expansion may also be occurring in their native range (Fomichev & Omelko, 2024). Regardless of the mechanism underlying the observed behavioral difference, knowledge on the adaptability of Joro spiders to novel conditions would be useful for assessing their impacts on ecosystems in areas where they newly establish.

ACKNOWLEDGEMENTS

We express our sincere gratitude to S. Hara, K. Hongo, R. Hori, K. Mine, B. Tanaka, D. Toshima for considerable assistance in our field work and K. Endo for important information on the study materials. The authors of this work declare that they have no conflicts of interest.

REFERENCES

Angulo E., Hoffmann B.D., Ballesteros-Mejia L., Taheri A., Balzani P., Bang A., Renault D., Cordonnier M., Bellard C., Diagne C., Ahmed D.A., Watari Y. & Courchamp F., 2022. Economic costs of invasive alien ants worldwide. Biological Invasions, 24: 2041–2060. https://doi.org/10.1007/s10530-022-02791-w

Bell J.R., Bohan D.A., Shaw E.M. & Weyman G.S., 2005. Ballooning dispersal using silk: world fauna, phylogenies, genetics and models. Bulletin of Entomological Research, 95: 69–114. https://doi.org/10.1079/ber2004350

Bell R.D., Rypstra A.L. & Persons M.H., 2006. The effect of predator hunger on chemically mediated antipredator responses and survival in the wolf spider *Pardosa milvina* (Araneae: Lycosidae). Ethology, 112: 903–910. https://doi.org/10.1111/j.1439-0310.2006.01244.x

Chinchio E., Crotta M., Romeo C., Drewe J.A., Guitian J. & Ferrari N., 2020. Invasive alien species and disease risk: An open challenge in public and animal health. PLoS Pathogens, 16: e1008922. https://doi.org/10.1371/journal.ppat.1008922

Chuang A., Deitsch J.F., Nelsen D.R., Sitvarin M.I. & Coyle D.R., 2023. The Jorō spider (*Trichonephila clavata*) in the southeastern U.S.: an opportunity for research and a call for reasonable journalism. Biological Invasions, 25: 17–26. https://doi.org/10.1007/s10530-022-02914-3

Cobb V.A., 1994. Effects of temperature on escape behavior in the cribellate spider *Oecobius annulipes* (Araneae: Oecobiidae). The Southwestern Naturalist, 39: 391–394.

Davis A.K. & Anerao A.V., 2023. Startle responses of Jorō spiders (*Trichonephila clavata*) to artificial disturbance. Arthropoda, 1: 60–67. https://doi.org/10.3390/arthropoda1020009

Fomichev A.A. & Omelko M., 2024. New for the Asian part of Russia taxa of spiders (Arachnida: Aranei). Far East Entomologist, 502: 12–20. https://doi.org/10.25221/fee.502.3

Giulian J., Jones T.C. & Moore D., 2024. Assessing the potential invasive range of *Trichonephila clavata* using species distribution models. Journal of Asia-Pacific Biodiversity, 17: 490–496. https://doi.org/10.1016/j.japb.2024.02.003

Grabarczyk E., Querejeta M., Tillman P.G., Wallace R.D., Barnes B., Meinecke C.D., Villari C., Gandhi K., LaForest J., Elliott M.J. & Schmidt J.M., 2003. DNA metabarcoding analysis of three material types to reveal Joro spider (*Trichonephila clavata*) trophic interactions and web capture. Frontiers in Ecology and Evolution, 11: 1177446. https://doi.org/10.3389/fevo.2023.1177446

Hedges L.V., 1981. Distribution theory for Glass's estimator of effect size and related estimators. Journal of Educational Statistics, 6: 107–128. https://doi.org/10.2307/1164588

Hoebeke E.R., Huffmaster W. & Freeman B.J., 2015. *Nephila clavata* L. Koch, the Joro Spider of East Asia, newly recorded from North America (Araneae: Nephilidae). PeerJ, 3: e763. https://doi.org/10.7717/peerj.763

Humphreys R.K. & Ruxton G.D., 2018. A review of thanatosis (death feigning) as an anti-predator behaviour. Behavioral Ecology and Sociobiology, 72: 22. https://doi.org/10.1007/s00265-017-2436-8

Lankau R.A., Nuzzo V., Spyreas G. & Davis A.S., 2009. Evolutionary limits ameliorate the negative impact of an invasive plant. Proceedings of the National Academy of Sciences of the USA, 106: 15362–15367. https://doi.org/10.1073/pnas.0905446106

Lee V.M.J., Kuntner M. & Li D., 2015. Ballooning behavior in the golden orbweb spider *Nephila pilipes* (Araneae: Nephilidae). Frontiers in Ecology and Evolution, 3: 2. https://doi.org/10.3389/fevo.2015.00002

Lodge D.M., 1993. Biological invasions: Lessons for ecology. Trends in Ecology & Evolution, 8: 133–137. https://doi.org/10.1016/0169-5347(93)90025-K

Nelsen D.R., Corbit A.G., Chuang A., Deitsch J.F., Sitvarin M.I. & Coyle D.R., 2023. Veni vidi vici? Future spread and ecological impacts of a rapidly expanding invasive predator population. Ecology and Evolution, 13: e10728. https://doi.org/10.1002/ece3.10728

Pan W.-J., Fang H.-Y., Zhang P. & Pan H.-C., 2016. The complete mitochondrial genome of *Nephila clavata* (Araneae: Nephilidae) Chinese population. Mitochondrial DNA Part A DNA Mapping, Sequencing, and Analysis, 27: 994–995. https://doi.org/10.3109/19401736.2014.926521

Phillips B.L., Brown G.P., Webb J.K. & Shine R., 2006. Invasion and the evolution of speed in toads. Nature, 439: 803. https://doi.org/10.1038/439803a

Prentis P.J., Wilson J.R.U., Dormontt E.E., Richardson D.M. & Lowe A.J., 2008. Adaptive evolution in invasive species. Trends in Plant Science, 13: 288–294. https://doi.org/10.1016/j.tplants.2008.03.004

R Core Team, 2021. R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

Sala O.E., Chapin III F.S., Armesto J.J., Berlow E., Bloomfield J., Dirzo R., Huber-Sanwald E., Huenneke L.F., Jackson R.B., Kinzig A., Leemans R., Lodge D.M., Mooney H.A., Oesterheld M., Poff N.L.R., Sykes M.T., Walker B.H., Walker M. & Wall D.H., 2000. Global biodiversity scenarios for the year 2100. Science, 287: 1770–1774. https://doi.org/10.1126/science.28754591770

Suzuki S. & Asano R., 2022. Note on egg sac attendance behavior of *Trichonephila clavata* (Araneae: Nephilidae): The possibility of maternal care. Japanese Journal of Entomology, 25: 60–62. https://doi.org/10.20848/kontyu.25.2_60

Viechtbauer W., 2010. Conducting Meta-Analyses in R with the metafor Package. Journal of Statistical Software, 36: 1–48.

Walker S.E. & Rypstra A.L., 2003. Hungry spiders aren't afraid of the big bad wolf spider, Journal of Arachnology, 31: 425–427. https://doi.org/10.1636/S02-63