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SHORT COMMUNICATION

Pattern and frequency of web decorating by *Argiope protensa* L. Koch, 1872 (Araneae: Araneidae)

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Abstract. Spiders in the genus *Argiope* Audouin, 1826 often include silken structures in their webs called decorations. Here, I report on the form and frequency of the vertical or linear decorations built by *A. protensa* L. Koch, 1872 as based on a survey of online digital imagery. Of 124 webs in 262 images clearly showing the web, 38.7% were decorated, less than for other congeners also sampled across their geographic range. The spider lays silk strips centered above and/or below the web's hub; however, one web appeared to have four strips arranged in a cruciate pattern. Unlike other *Argiope* whose decorations consist of zigzagging bands, *A. protensa* weaves a derived cottony decoration of jagged strips reminiscent of those in Uloboridae. Large and geographically broad surveys of spider behavior and web structure are possible using online databases of natural-history observations.

Keywords: Stabilimenta, citizen science

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Many species of orb-weaving spiders in the Araneidae and Uloboridae often include in their webs strips or swatches of silk, called decorations or stabilimenta, whose function has long been debated. Experiments support a role for the structure in prey attraction (Craig & Bernard 1990), predator avoidance (Blackledge & Wenzel 1999), or warning to flying birds of the web's location (Eisner & Nowicki 1983), as well as indicate that its function(s) are likely balanced against significant and varied costs (Yeh et al 2015).

A frequent model for these studies has been *Argiope* Audouin, 1826 (Araneidae), a genus of 86 nominal species (World Spider Catalog 2020) distributed globally, all of whom probably decorate their webs. Decoration form has been reported for 38 (44%) evolutionarily disparate species in the group (Cheng et al. 2010) and indicates a limited set of decoration types fixed within species. Still, the full range of decoration form and frequency remains unknown for the majority of *Argiope*, including those potentially evincing novel structure and pattern.

Here, I report the form and frequency of web decorations woven by *Argiope protensa* L. Koch, 1872, largely tallied from citizen-science databases of digital imagery. The species is distinctive and easily identified from photos: it is smaller than many *Argiope* (adult females average 10 mm body length), less gaily colored, and is one of only two species in the genus with an elongate and pointed abdomen bearing longitudinal, rather than transverse, stripes. The species is known from Australia, Indonesia, New Caledonia, and New Zealand (Chrysanthus 1971). While widespread, it is rather uncommon where it occurs and challenging to find as its web is often concealed in thick vegetation.

I retrieved images of *A. protensa* from the online databases Canberra Nature Map (online at https://canberra.naturemapr.org), iNaturalist (https://inaturalist.org), which includes migrated records from the retired site BowerBird bowerbird.org.au), and, via the Atlas of Living Australia (https://ala.org.au), NatureShare (https://natureshare.org.au), OzAtlas (https://researchdata.edu.au/ala-species-sightings-ozatlas), and QuestaGame (https://questagame.com). Other sites also collectively curated a trove of images: Bryce Photography (https://brycephotography.co.nz), Dave's Garden (https://davesgarden.com), Esperance Fauna (https://esperance wildlife.blogspot.com), Find-A-Spider Guide (https://findaspider.org.au), Flickr (flickr.com), Twitter (twitter.com), and retired site Wild South Australia (https://wildsouthaustralia.org.au). I then removed duplicate images and those with misidentified spiders (usually, the sympatric and similar-looking *A. probata* Rainbow, 1916). The remaining images were reviewed for the clear presence and pattern of web decorations. Those showing damaged webs or partial views potentially omitting decorations were excluded. For each image, I also harvested metadata bearing on environment or climate, such as latitude, longitude, and date of observation. Error around sample frequencies was estimated as the 95% confidence intervals of a binomial proportion. Differences in frequencies were analyzed with log-likelihood ratio tests. The dataset and code are available from the author.

From online repositories, I retrieved 641 unique images of 228 "sightings" (usually of single spiders) by 163 observers of *A. protensa*. Excluding images not clearly showing the web region where decorations potentially occur left 262 images by 97 observers of 124 webs occupied by late-instar to adult female spiders from Australia (104 webs), Indonesia (1), and New Zealand (19) on which I based the following analyses and discussion.

As first noted by Whyte & Anderson (2017), *Argiope protensa* weave vertical to near vertical "linear" decorations *sensu* Herberstein et al. (2000), which are built by about one-third of other *Argiope* spp. (Cheng et al. 2010). I found that about half of the decorations of *A. protensa* consisted of a single arm (Fig. 1a, 2b), all of which extended below the hub (Fig. 2b), as occurs among other *Argiope* that build linear decorations (Marples 1935; Blackledge 1998). Nearly half of the decorations of *A. protensa* consisted of two vertical arms radiating from either side of the hub (Fig. 1b). However, the arms never continued through the hub as seen in many *Argiope* spp. (Herberstein et al. 2000). Finally, a single web of *A. protensa* appeared to include a four-armed decoration (Fig. 1c), a design typical of about half of *Argiope* spp. (Cheng et al. 2010). I am unaware of published reports of other species with primarily vertical linear designs that occasionally build a four-armed decoration.

Overall, 38.7% ($n = 124$) of *A. protensa* webs photographed across the spider's range had decorations. This point estimate fell within the 95% confidence intervals of all geographic subsets examined, except northern Australia (Fig. 2a). This suggested comparisons of geographic partitions, where I found one difference greater than expected by chance between frequencies south and north of 30° S. This latitude roughly divides, respectively, the temperate zone of south-eastern Australia from warmer, mostly drier Australia. If the

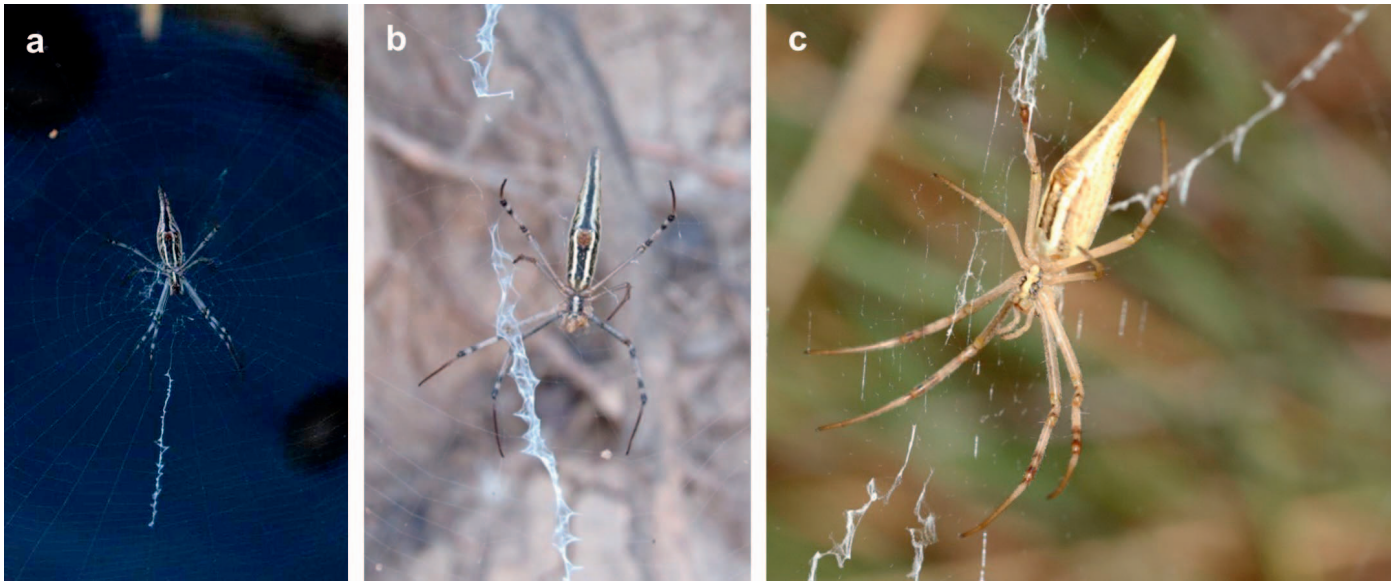

Figure 1.—Web decorations of *Argiope protensa*: a. one-armed decoration built below the hub of the web, Sunda, Indonesia (photo by Heri Andri). b. Two-armed decoration, South Australia (photo by ceejay93). c. Possible four-armed decoration, New South Wales, Australia (photo by Matt Campbell). All photos CC BY-NC 4.0.

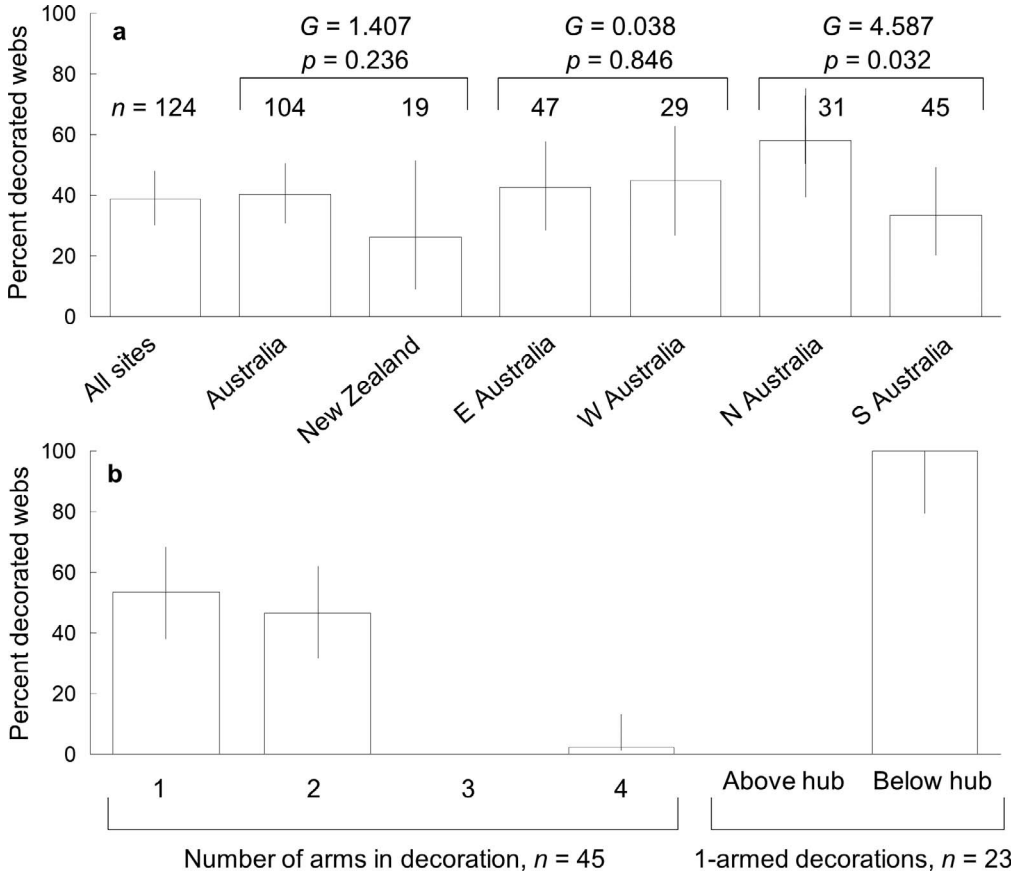

Figure 2.—Frequency of decorations in *Argiope protensa*: a. Frequency of decorations by geographic region, including Australia east and west of 135° E longitude and north and south of 30° S latitude. For all likelihood-ratio tests, $df = 1$. b. Frequency of decoration patterns.

Table 1.—Decoration frequencies of *Argiope* spp. sampled across their geographic ranges. Worldwide tallies given with and without the large Panama dataset.

Species	Site	All webs	Decorated webs	%	Reference
A. aemula (Walckenaer, 1841)	Philippines	547	489	89.4	Abrenica-Adamat 2015
	Papua New Guinea	83	76	91.6	Robinson & Robinson 1974
	Taiwan	78	64	82.1	Cheng and Tso 2007
	Combined sites	708	629	88.8	
A. argentata (Fabricius, 1775)	Bahamas	282	247	87.6	Schoener & Spiller 1992
	Costa Rica	122	91	74.6	Uhl 2008
	Daphne, Galapagos	141	35	24.8	Lubin 1975
	Jamaica	65	49	75.4	Marples 1969
	Panama	2614	902	34.5	Robinson & Robinson 1970
	Santa Cruz, Galapagos	134	56	41.8	Lubin 1975
	Venezuela	86	36	41.9	Velásquez Escalante et al. 2016
	Combined sites	3254	1490	42.2	
A. bruennichi (Scopoli, 1772)	England	160	71	44.0	Bush et al. 2008
	France	90	61	67.8	Marples 1935
	Germany	134	97	72.4	Walter 2008
	Slovakia	119	89	74.8	Prokop & Grygláková 2005
	South Korea	82	49	59.8	Kim 2015
	Combined sites	585	367	62.7	
A. protensa L. Koch, 1872	Australia	104	42	40.4	This study
	New Zealand	19	5	26.3	This study
	Combined sites	123	47	38.7	
A. trifasciata (Forsskål, 1775)	Ghana	752	346	46.0	Edmunds 1986
	Ohio, U.S.A.	157	103	65.6	Blackledge & Wenzel 2001
	Ontario, Canada	337	108	32.0	Crowe 2009
	Pakistan	232	102	44.0	Butt et al. 2017
	Combined sites	1478	659	44.6	
Combined species	Worldwide	6065	3184	52.5	
	Excluding Panama	3451	2282	66.1	

result holds with denser sampling, then perhaps there exists a different ecological role or need for decorating webs in different climates, apparently with greater decorating in warmer zones.

The frequency of decorated webs of *A. protensa* appeared lower than for other species of *Argiope*. Few species of spiders have been surveyed for web decorating at a comparable scale. The four other *Argiope* spp. that have been sampled across their geographic range, albeit intensely at a few widespread sites, possess overall decoration frequencies higher than for *A. protensa*, ranging from 42.2% to 88.8% with a combined average for the genus, including *A. protensa*, of at least 52.2% (Table 1). If these values are representative, then at the scale examined, *A. protensa* decorates its web less often than many other *Argiope*.

Finally, decorations of *A. protensa* also differed in detail and construction from other *Argiope* studied to date. Most *Argiope* decorate by primarily laying a sheet of silk across two adjacent parallel web strands (radial strands in the case of linear and cruciate decorations), then pulling the sheet back and forth in this manner towards the web's hub, producing a taut band "en forme de zigzag" (Vinson 1863). By contrast, *A. protensa* primarily alternates loosely laid silk between a single radial strand and an adjoining but orthogonal spiral strand on either side of the radial, giving their decorations a flocculent and sawtoothed appearance (Fig. 1).

In this, the decorations of *A. protensa* more resemble those from several decorating genera in Uloboridae, such as *Octonoba* Opell, 1979 (Wu 2018) and *Uloborus* Latreille, 1806 (Eritella 2020). Uloborids and *Argiope* are phylogenetically distant (Wheeler et al. 2017) and *A. protensa* is further derived within a speciose lineage of argiopine taxa (Cheng & Kuntner 2014) that is otherwise uniform in the use of parallel-strand decorating (Cheng et al. 2010). Hence, sawtooth decorations probably arose independently in the two groups. Like decorating uloborids, *A. protensa* is relatively small compared to many *Argiope*, builds a relatively delicate web that is often concealed in low vegetation. It is tempting then to wonder whether their analogous decoration is solely the product of design constraints or from a shared ecology.

To conclude, online digital imagery is increasingly employed in large and geographically comprehensive surveys of organismal structure and distribution (e.g., Pauly et al. 2020). Using such observations, I found that decorations woven by *A. protensa* are unusual among *Argiope*. Their decorations were less often built, the variation in patterns differed, they were uniquely constructed, and their similarity to uloborid decorations likely indicates an independent evolutionary acquisition.

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