ELBA BIOFLUX

Extreme Life, Biospeology & Astrobiology International Journal of the Bioflux Society

Salient features of the orb-webs of the grass cross spider, *Argiope catenulata* (Araneae: Araneidae)

Liza R. Abrenica-Adamat, Rosendo C. Catindig Jr.

Department of Biological Sciences, Mindanao State University-Iligan Institute of Technology, Tibanga Iligan City, Philippines. Corresponding author: L.R. Abrenica-Adamat, lizadamat@gmail.com

Abstract. This study primarily aims to describe the salient features of the orb-webs of Argiope catenulata. Specifically, this study aims to examine the prey-attraction hypothesis as function of stabilimentum and address whether there is a trade-off between web size and stabilimentum-building activity. The spider size, number of prey, size of prey and web design such as occurrence, type and size of stabilimentum, web diameter, web area and mesh distance were recorded. The data were then used to determine the relationship between parameters. The results show that the occurrence of stabilimentum is not an obligatory component of the orb-web. Intraspecific variation in stabilimentum structure was observed. The juveniles (<0.60cm=body length) commonly spin discoid stabilimentum while adults (>0.60cm=body length) spin the cruciate type. The cruciate type can be a 1-armed, 2-armed, 3-armed or 4-armed. The observed variations in web design may have affected the prey capture ability of the spider webs. Large individuals were more likely to spin large webs (large web size, long web diameters) with large meshes and long stabilimentum. Large webs with large meshes were more likely to capture more prey and large-sized prey suggesting an increased overall hunting mechanism of female A. catenulata. No direct correlation of stabilimentum with number and size of prey. However, stabilimentum as a prey attractant could still be evaluated in a study as to the higher number of prey captured in webs with stabilimenta as compared to webs without stabilimenta. The idea that spiders exhibit a trade-off between web size and stabilimentum-building is not supported in the present study. Key Words: stabilimentum, orb-web, Argiope catenulata, prey, web design.

Rezumat. Acest studiu urmăreste în primul rând să descrie trăsăturile proeminente ale pânzei de păianjen circulare țesute de Argiope catenulata. În mod specific, acest studiu își propune cercetarea ipotezei potrivit căreia stabilimentul are funcție de atragere a prăzii și să verifice dacă este o compensație între dimensiunea pânzei și activitatea de realizare de stabiliment. Dimensiunea păianjenului, numărul prăzii, dimensiunea prăzii și trăsături de design ale pânzei precum prezența, tipul și dimensiunea stabilimentului, diametrul pânzei, suprafața pânzei și distanța ochiurilor au fost înregistrate. Datele au fost apoi folosite pentru a determina relatia dintre parametrii. Rezultatele arată că prezența stabilimentului nu este o componentă obligatorie a pânzei circulare de păianjen. A fost observată o variație intraspecifică în structura stabilimentului. Juvenilii (≤0.60cm=lungimea corpului) țes în mod obișnuit stabiliment discoid în timp ce adulții (>0.60cm= lungimea corpului) țes în cruce. Tipul în cruce poate fi cu un brat, două brate, trei brate sau patru brate. Variatiile observate în design-ul pânzei se poate să fi afectat capacitatea de capturare a prăzii de către pânzele de păianjen. Indivizii mari este mult mai probabil să țeasă pânze mari (dimensiune mare a pânzei, diametre mari ale pânzei) cu ochiuri mari și stabiliment lung. Pânze mari cu ochiuri mari a fost mult mai probabil să captureze mai multă pradă și pradă mare sugerând un mecanism de vânătoare pe ansamblu crescut al femelei de A. catenulata. Nu există o corelație directă între stabiliment și numărul și dimensiunea prăzii. În orice caz, stabilimentul ca și atractant al prăzii poate fi evaluat într-un studiu privind un număr mai mare de pradă capturată în pânze cu stabilimente, în comparație cu pânzele fără stabilimente. Ideea că păianjenii prezintă o compensație între dimensiunea pânzei și formarea stabilimentului nu este susținută de prezentul studiu.

Cuvinte cheie: stabiliment, pânză circulară, Argiope catenulata, pradă, design-ul pânzei.

Introduction. All orb-web spiders use webs as an excellent prey capture device and for defence. Spider's experience in web-building and prey capture may also contribute to individual variation of orb-web design (Adamat et al 2011; Abrenica-Adamat 2013a).

Variation in web design affects the prey capture ability of the spider webs (Heiling & Herberstein 2000; Venner & Casas 2005; Sandoval 1994).

Some orb-web spiders add conspicuous, white zigzag silk decorations termed stabilimenta onto the hub of the webs. Obviously, the frequency of occurrence, type and form of stabilimenta vary within species. The structure and function of stabilimentum have become the focus of interest to researchers for over a century. Among *Argiope* spiders, the discoid stabilimenta are white silk closely interwoven in the hub of the spiders while cruciate stabilimenta are zigzag line formation of white silk arranged in a complete or incomplete "X" pattern.

Among the major hypotheses regarding the function of stabilimentum, the preyattraction hypothesis (Craig & Bernard 1990; Craig 1994; Hauber 1998; Tso 1996, 1998a, 1998b) is the most popular. According to the prey-attraction hypothesis, the presence of stabilimentum increases the spider's foraging success since these constructs reflect ultraviolet (UV) light and many insects are attracted to UV (Li et al 2004) because it indicates open sky, or a safe light path (Goldsmith 1961; Hu & Stark 1997; Watanabe 1999a, 1999b). According to Li (2005), spiders that decorate their webs at higher frequency intercept more prey and grow faster.

The present study was conducted primarily to describe the salient features of the orb-web of *Argiope catenulata*. Also, this study aims to investigate the prey-attraction function of stabilimentum and to examine whether there is a trade-off between web size and stabilimentum-building activity. In this paper, decorated webs refer to webs with stabilimentum while non-decorated webs are webs without stabilimentum.

Materials and Methods

Study area and spider specimen. The field survey was conducted in the rice field of Brgy. Blancia, Molave, Zamboanga del Sur, Philippines from May 2 to December 30, 2013. The vast agricultural area of rice cultivation serves as a habitat for different insects which may provide a sustainable food resource for *Argiope catenulata*. A total of 287 webs were observed, 43 webs of juvenile and 244 webs of adult spiders. The distinguishing characteristics for identification were based on the description of Barrion & Litsinger (1995). For comparison purposes, spiders were assigned to five size categories based on their body size: A :< 0.60 cm; B: 0.60-0.79 cm; C: 0.80-0.99 cm; D: 1.00-1.29 cm; E :> 1.29 cm. Spider less than or equal to 0.60 cm was classified as juvenile while adult was measured with greater than 0.60 cm in size.

Images of the spider and its orb-web taken with a ruler were imported to UTHSCSA Image Tool Software to quantify the spider's size, stabilimentum arm length, mesh distance, and prey size. Noted also in the study was the absence or presence of stabilimentum, stabilimentum type and pattern, and the number of prey captured. Using a measuring tape, the web vertical diameter and web horizontal diameter were acquired by determining the distance between the outermost sticky ends of the adjacent side of the web. All measurements are in cm scale. The total web area (web size) was then calculated using the formula by Blackledge (1998):

$$\mathsf{A} = \left(\frac{dh}{2} \right) \left(\frac{dh}{2} \right) \times \pi$$

where A is the total web area, dv is the web vertical diameter, dh is the web horizontal diameter and π is the pi value which has an approximate value of 3.1415.

Statistical analysis. Linear Regression Analysis was used to determine correlation of prey capture, spider size and prey size with the web variables. Mann-Whitney Comparison Test was used to evaluate significant difference on measurement of web variables as affected by the presence and absence of stabilimentum. The statistical measurement was aided with the software PAST (Hammer et al 2001).

Results and Discussion. Intraspecific variation in orb-web design was observed among *Argiope catenulata* spiders. In particular, the occurrence of the web decoration

(stabilimentum) was not observable in all webs (Figure 1A-B). Only 208 webs (72.47%) were decorated. Among the adults, only 172 webs (70.49%) were decorated. Among the juveniles, only 36 webs (83.72%) were decorated. The absence of stabilimentum in some webs indicates that spinning of stabilimentum is not an obligatory component in web building among *Argiope catenulata* spiders.



Figure 1. Frequency of decorated and non-decorated webs (A) and frequency of occurrence and different kinds of stabilimentum among size categories (A: <0.60 cm; B: 0.60-0.79 cm; C: 0.80-0.99 cm; D: 1.00-1.29 cm; E :> 1.29 cm) of Argiope catenulata (B).

The webs of *Argiope catenulata* contain either discoid or cruciate stabilimentum. The discoid type occurred only in smaller spiders with less than 0.80 cm sizes. In contrast, the cruciate type was observed in all size categories but appeared more frequent in spiders with greater body length (body size>0.60 cm. These results were also observable in different studies of *Argiope* in which variation of stabilimentum is dependent on the spider's size demonstrating an ontogenetic polymorphism in stabilimentum structure (Nentwig & Heimer 1987; Ewer 1972; Abrenica-Adamat et al 2013a). Few of the juveniles spun a discoid with a part of cruciate which resembles like two superimposing types of web decoration (cruciate and discoid stabilimentum) probably a transition from discoid to cruciate design. It has been suggested that the ontogenetic shift from discoid to cruciate may indicate that stabilimentum function varies throughout the spider's life history, hence, might serve different functions in juveniles and adults (Li et al 2004).

Table 1

Size Categories						
Stab Arm	А	В	С	D	E	Total
	(<.60 cm)	(0.679 cm)	(.8099 cm)	(1-1.29 cm)	<u>(></u> 1.30 cm)	
1-arm	13(72.2)	24(72.7)	37(62.7)	32(59.3)	14(66.7)	119 (64.9)
2-arm	4(22.2)	5(15.2)	22(37.3)	20(37.0)	7(33.3)	58 (31.4)
3-arm	0	2(6.06)	0	2(3.7)	0	4(2.2)
4-arm	1(5.6)	2(6.06)	0	0	0	3 (1.6)
N	18	33	59	54	21	185

Occurrences of cruciate type in various size categories of female *A. catenulata.* Frequencies are given in parentheses.

Legend: Stab=Stabilimentum

Cruciate stabilimentum also varies in number of arms, stabilimentum arm length and orientation of arms (Table 1). There were four forms of cruciate stabilimenta in orb-webs of *Argiope catenulata* observed: 1-armed (59.44 %), 2-armed (37.78 %), 3-armed (1.11 %) and 4-armed (1.67 %) discontinuous cruciate stabilimentum. The 4-armed stabilimenta was only observed in spiders of smaller sizes varying from <0.60cm-0.79cm. No relationship was observed between spider size and number of stabilimentum arm (Table 2).

Table 2

Web Variables	Linear Correlation	
	R	р
Occurrence of stabilimentum	-0.1442	0.0145
Web vertical diameter (cm)	0.5030	0.0000
Web horizontal diameter (cm)	0.5036	0.0000
Web size (cm ²)	0.4680	0.0000
Mesh distance (cm)	0.6545	0.0000
No. of prey intercepted	0.1849	0.0017
Prey size (cm)	0.2822	0.0000
No. of stabilimentum arms*	0.0134	0.8566
Length of stabilimentum *	0.0375	0.0000
Discoid stabilimentum area (cm ²)**	0.6593	0.0000

Correlation of spider's size between its web variables and the total number of prey captured (N=287)

Legend *N=185;**25; correlation is significant at the 0.05 level

Recent studies suggest that individual spiders' variation in orb-web design is linked to prey capture efficiency (Sandoval 1994; Rypstra 1982; Uetz et al 1978; Sherman 1994; Higgins & Buskirk 1992). As shown in Table 2, larger spiders were less likely to spin stabilimentum. However, larger spiders were more likely to spin large webs with large mesh distances, large stabilimentum, and tended to capture more prey and large prey (such as grasshoppers, dragonflies, blowflies and moths, pers. obs.). Building large web with large stabilimentum and long meshes could be one of the spiders' strategies to increase prey capture abilities as their nutritional needs tend to increase with increasing body size. It has been hypothesized that the sizes of prey targeted by spiders are also likely to increase as spiders develop (Sensenig et al 2011) since rare but large prey items play a crucial role in spiders reaching adulthood and in maximizing fecundity (Venner & Casas 2005).

The length of stabilimentum was positively correlated with web vertical diameter, web horizontal diameter and web area (Table 3). Present results differ from previous field and laboratory observations (Adamat et al 2011; Abrenica-Adamat 2013a, 2013b) which showed that larger webs tended to have shorter stabilimentum which is a trade-off between web size and stabilimentum activity. Only the mesh distance showed a positive correlation with presence of stabilimentum and stabilimentum length. It should be noted that there is no direct correlation of the number of prey captured with presence or stabilimentum length (Table 3 and 4), giving no evidence of the prey-attraction hypothesis as function of stabilimentum.

Table 3

	Presence of Stabilimentum (N=287)		Stabilimentum Length (N=210)	
Web Variables				
	R	p	R	Р
Web horizontal diameter (cm)	0.0341	0.5651	0.2486	0.0007
Web vertical diameter (cm)	0.0027	0.9640	0.3928	0.0000
Mesh distance (cm)	0.1835	0.0018	0.3625	0.0000
Web size (cm ²)	0.0155	0.7380	0.3450	0.0000
No. of prey intercepted	0.0124	0.8390	0.0228	0.7589
Prey size	0.0381	0.7412	0.0856	0.2371
Completion is significant at 0.05 level				

Relationship of presence of stabilimentum and stabilimentum length to web variables in *Argiope catenulata*

Correlation is significant at 0.05 level

In contrast, the number of prey captured increased with increasing web size, web horizontal/vertical diameter, and mesh distance (Table 4). It can be deduced from the results that the increased likelihood of prey interception can be more associated with the increased size of the web rather than the presence and length of stabilimentum.

Table 4

Linear Correlation of the number of prey intercepted with the spider's size and web variables in *A. catenulata* (N=287)

	Linear Regression			
Web Variables	R	Р		
Spider size (cm)	0.1849	0.0017		
Web horizontal diameter (cm)	0.1967	0.0008		
Web vertical diameter (cm)	0.2291	0.0000		
Mesh distance (cm)	0.1835	0.0018		
Web size (cm ²)	0.1803	0.0022		
Occurrence of stabilimentum	0.0124	0.8390		
Length of stabilimentum (cm) $*$	0.0228	0.7589		

Legend *N=185; correlation is significant at the 0.05 level

The prey size may be linked to the distance between capture spirals (mesh distance). As shown in Table 5, the prey size is positively correlated with mesh distance, confirming that webs with large web meshes are more likely to capture large prey. Orb-webs with narrow meshes and longer meshes are thought to target large and small prey respectively (Murakami 1983; Sandoval 1994; Herberstein & Heiling 1998; Schneider & Vollrath 1998). The spiders may have designed their web meshes in response to detected prey size of their previous prey interception experiences. Recent studies (Adamat et al 2011) have shown that spiders fed with large-sized prey (e.g. grasshoppers, mealworms), spun webs with larger mesh widths compared to webs spun by spiders fed with small-sized prey (*Drosophila* spp.). Web with smaller mesh height as observed in the study still captured large prey but much more of the smaller prey.

The size of prey captured also increase with increasing web size (Table 5) which may be due to the increasing mesh distance as web size increases (Linear Regression between web size and mesh distance: R=0.433, p>0.00001). However, it should also be

noted that the common prediction that larger meshes target larger prey may not always be true (Herberstein & Heiling 1998; Blackledge & Zevenbergen 2006). For instance, Blackledge & Eliason (2007) reported that webs with narrower meshes perform better at capturing large prey.

Table 5

	Linear Regression			
Web Variables	R	Р		
Occurrence of stabilimentum	0.0126	0.8320		
Spider size (cm)	0.2822	0.0000		
Length of stabilimentum (cm)*	0.0782	0.1867		
Disc stabillimentum area (cm ²)**	0.0315	0.8816		
Web size (cm ²)	0.1602	0.0065		
Web horizontal diameter (cm)	0.2000	0.0007		
Web vertical diameter (cm)	0.1976	0.0008		
Mesh distance (cm)	0.2520	0.0000		

Correlation between variables in relation to prey size in all webs (N=287)

Legend *N=185;**25; correlation is significant at the 0.05 level

Although there was no direct correlation between the number of prey intercepted and presence or stabilimentum length (see Table 4) however, relative to the number of prey intercepted between decorated and non-decorated webs, it can be observed that more prey was recorded in webs with stabilimentum (Table 6). Hence, we could not disregard the prey-attraction function of the stabilimentum. UV-reflectance as a key luring feature of prey-attraction has been supported by several studies. Presence of stabilimentum increases a spider's foraging efficiency by reflecting ultraviolet light since most insects are attracted to ultraviolet reflectance (Craig & Bernard 1990; Craig 1994; Hauber 1998; Tso 1996, 1998a, 1998b; Li et al 2004; Goldsmith 1961; Hu & Stark 1997; Watanabe 1999a, 1999b; Galvez 2009).

Table 6

stabilitientum) and decorated (with stabilitientum)					
Web Parameters	Decorated	Non-decorated	Z	U	Monte Carlo
	(N=210)	(N=76)			p
Web vertical diameter (cm)	23.46±12.32	23.48±13.90	-1.764	6019	0.348
Web horizontal diameter (cm)	22.88±10.91	22.13±10.14	-0.691	7516	0.5949
Web size (cm ²)	1614.80±1403.92	1573.62±1689.81	-0.818	7438	0.8342
Mesh distance (cm)	0.23±0.095	0.27±0.11	-2.14	6622	0.015
No. of prey intercepted	9.10±13.34	4.68±8.2917	-2.80	6227	0.0076

Man-Whitney (Two Samples) Pairwise comparison between non-decorated (no stabilimentum) and decorated (with stabilimentum)

In the present study, the prey species observed were mostly flying dipteran insects (mosquitoes: 62.8 % and fruit flies: 31.13 %) which were reported to have photoreceptors that are very sensitive in the ultraviolet range (Hu & Stark 1997; Bishop 1974; Muir et al 1992). A web with stabilimentum reflects UV light, provides floral guides, and deceives their prey by mimicking a food resource (Craig 1994; Watanabe

1999a, 1999b). Also flying insects are attracted to UV bright silk because it characterizes an open sky, providing free space for flying or escape routes (Craig 1994).

Based on the present results, it is reasonable to assume that the increased likelihood of prey interception was not solely associated with web size and web meshes but can be a concerted effect of web size and stabilimentum-building activity of the spider. This finding did not support the hypothesis that web size and stabilimentum-building activity are two alternative strategies among *Argiope* spiders, and that there is trade-off between stabilimentum-building and web area (*Araneus eburnus*: Bruce et al 2004; *Argiope appensa*: Hauber 1998 and Adamat et al 2011, Abrenica-Adamat 2013a, 2013b; *A. keyserelingi*: Walter et al 2008; Herberstein et al 2000; *A. trifasciata*: Tso 1999; *A. aurantia* and *A. trifaciata*: Blackledge 1998 and Crowe 2009).

Conclusions. The stabilimenta is an optional component of webs among *A. catenulata*. Intra-species variation in stabilimentum structure is dependent on the ontogenetic stage. Juveniles usually spin discoid stabilimenta and sexually mature individuals spin cruciate stabilimenta which vary in the number of discontinuous arms. Variations in web design exist within species. The observed variations in web design may have affected the prey capture ability of the spider webs. For instance, large individuals were more likely to spin webs with large capture area, long vertical and horizontal diameters, large meshes and long stabilimentum. Large webs with large meshes were more likely to capture more prey and large-sized prey suggesting an increased overall hunting mechanism of female *A. catenulata*. No direct correlation of stabilimentum with number and size of prey. However, stabilimentum as a prey attractant could still be evaluated in a study as to the higher number of prey captured in webs with stabilimenta as compared to webs without stabilimenta. The idea that spiders exhibit a trade-off between web size and stabilimentum activity is not supported in the present study.

The results gathered were not subjected to possible environmental factors and prey captured was based only on the prey intercepted in the web in the moment of observation and not the actual consumption, thus, prey presence in a web was only an approximation of spider's foraging success. Therefore, an enclosure study is recommended to compare the prey-capture rates in decorated and undecorated webs and simultaneously address the hypotheses that web size and stabilimentum-building are alternative strategies among these spiders. Varying *Argiope* species must also be evaluated and varying geographical locations of spiders is highly advised.

References

- Abrenica-Adamat L. R., Bermudo E. E., Torres M. A. J., Dupo A. L. B., Demayo C. G., 2013a Describing frequency of occurrence, size and stabilimentum-building behavior of four species of orb-web building *Argiope* spiders. ELBA Bioflux 5(1):28-37.
- Abrenica-Adamat L. R., Torres M. A. J., Gorospe, J. A., Demayo C.G., 2013b Describing stabilimentum-building and other web characteristics in selected fed and unfed *Argiope* spiders. Annals of Biological Research 4(11):55-59.
- Adamat L. A., Torres M. A. J., Gorospe J. A., Barion-Dupo A. L. A., Demayo C. G., 2011 Orb-web Design of Garden Spider, *Argiope appensa* (Walckenaer, 1841)(Araneae:araneidae). Australian Journal of Basic and Applied Sciences 5(3): 175-184.
- Barrion A. T., Litsinger A. A., 1995 Riceland Spiders of South and Southeast Asia. CAB International/International Rice Research Institute. University Press, Cambridge.
- Bishop L. G., 1974 An ultraviolet photoreceptor in dipteran compound eye. Journal of Comparative Physiology 91:267-275.
- Blackledge T. A., 1998 Stabilimentum variation and foraging success in *Argiope aurantia* and *Argiope trifasciata* (Araneae: Araneidae). Journal of Zoology 246:21-27.
- Blackledge T. A, Zevenbergen J. M., 2006 Mesh width influences prey retention in spider orb webs. Ethology 112:1194–1201.

- Blackledge T. A., Eliason C.M., 2007 Functionally independent components of prey capture are architecturally constrained in spider orb webs. Biology Letters 3(5): 456–458.
- Bruce M. J., Heiling A. M., Herberstein M. E., 2004 Web decorations and foraging success in *Araneus eburnus* (Araneae:Araneidae). Annales Zoologici Fennici 41:563-575
- Craig C. L., Bernard G. D., 1990 Insect attraction to ultraviolet-reflecting spider webs and web decorations. Ecology 71:616–623.
- Craig C. L., 1994 Pedator foraging behaviour in response to perception and learning by its prey: interactions between orb-spinning spiders and stingless bees. Behavioral Ecology and Sociobiology 35:45-52.
- Crowe S. A., 2009 Exploring the functions of stabilimentum in the banded garden spider, *Argiope trifasciata.* M.S.Thesis. Queen's University, Canada. p 1-94.
- Ewer R. F., 1972 The devices in the web of the West African spider *Argiope flavipalpis*. Journal of Natural History 6:159-167.
- Gálvez D., 2009 Frame-web-choice experiments with stingless bees support the preyattraction hypothesis for silk decorations in *Argiope savignyi*. Journal of Arachnology 37(3):249-253.
- Goldsmith T. H., 1961 The color vision of insects. In: Light and Life (Ed. by W. E. M. Elroy & B. Glass). Johns Hopkins University Press, Baltimore. pp. 771-794.
- Hammer Ø., Harper D. A. T., Ryan P. D., 2001 PAST:Paleontological statistics software package for education and data analysis. Palaeontologia Electronica 9pp.
- Hauber M. E., 1998 Web decoration and alternative foraging tactics of the spider *Argiope appensa*. Ethology, Ecology and Evolution 10:47-54.
- Heiling A. M., Herberstein M. E., 2000 Interpretations of orb-web variability: a review of past and current ideas Ekologia-Bratislava 19:97-106.
- Herberstein M. E., Heiling A. M., 1998 Does mesh height influence prey length in orb-web spiders (Araneae)? European Journal of Entomology 95:367-371.
- Herberstein M. E, Craig C. L., Elgar M. A., 2000 Foraging strategies and feeding regimes: web and decoration investment in *Argiope keyserlingi* Karsch (Araneae: Araneidae). Evolutionary Ecology Research 2:69-80.
- Higgins L. E., Buskirk R. E., 1992 A trap-building predator exhibiting different tactics for different aspects of foraging behaviour. Animal Behaviour 44: 485–499.
- Hu G. G., Stark W. S., 1977 Specific receptor input into spectral preference in *Drosophila*. Journal of Comparative Physiology 121:241-252.
- Li D., 2005 Spiders that decorate their webs at higher frequency intercept more prey and grow faster. Proceedings of the Royal Society B 272:1753–1757.
- Li D., Lim M. L., Seah W. K., Tay S. L., 2004 Prey attraction as a possible function of discoid stabilimenta of juvenile orb-spinning spiders. Animal Behaviour 68:629–635.
- Muir L. E., Thorne M. J., Kay B. H., 1992 *Aedes aegypti* (Diptera:Culicidae) vision: spectral sensitivity and other perceptual parameters of the female eye. Journal of Medical Entomology 29:278-281.
- Murakami Y., 1993 Factors determining the prey size of the orb-web spider *Argiope amoena* (L. Koch) (Argiopidae). Oecologea 57: 72-77.
- Nentwig W., Heimer S., 1987 Ecological aspects for spider webs. In: Ecophysiology of Spiders (Nentwig W. ed). Springer, Berlin, 211-228.
- Rypstra A. L., 1982 Building a better insect trap: an experimental investigation of prey capture in a variety of spider webs. Oecologia 52: 31–36.
- Sandoval C. P., 1994 Plasticity in web design in the spider *Parawixia bistriata*: a response to variable prey type. Functional Ecology 8:701-707.
- Sensenig A. T., Agnarsson I., Blackledge A. T., 2011 Adult spiders use tougher silk: ontogenetic changes in web architecture and silk biomechanics in the orb-web spider. Journal of Zoology 285(1):28-38.
- Schneider J. M, Vollrath F., 1998 The effect of prey type on the geometry of the capture web of *Araneus diadematus*. Naturwissenschaften 85:391–394.
- Sherman P. M., 1994 The orb-web: an energetic and behavioural estimator of a spider's dynamic foraging and reproductive strategies. Animal Behaviour 48:19–34.

- Tso I.-M., 1996 Stabilimentum of the Garden Spider *Argiope trifasciata*: a possible prey attractant. Animal Behaviour 52:183-191.
- Tso I.-M., 1998a Isolated spider web stabilimentum attracts insects. Behaviour 135:311– 319.
- Tso I.-M., 1998b Stabilimentum-decorated webs spun by *Cyclosa conica* (Araneae, Araneidae) trapped more insects than undecorated webs. Journal of Arachnology 26:101–105.
- Tso I.-M., 1999 Behavioral response of *Argiope trifasciata* to recent foraging gain: a manipulative study. American Midland Naturalist 141:238–246.
- Uetz G. W., Johnson A. D., Schemske D. W., 1978 Web placement, web structure, and prey capture in orb-weaving spiders. Bull Br Arachnological Society 4:141–148.
- Venner S. J., Casas J., 2005 Spider webs designed for rare but life-saving catches. Proceedings of the Royal Society London. Biological Sciences 272:1587-1592.
- Walter A., Elgar M. A., Bliss P., Moritz R. F. A., 2008 Wrap attack activates webdecorating behavior in *Argiope* spiders. Behavioural Ecology 19(4):799-804.
- Watanabe T., 1999a The influence of energetic state on the form of stabilimentum built by *Octonoba sybotides* (Araneae: Uloboridae). Ethology 105:719-725.
- Watanabe T., 1999b Prey attraction as possible function of the silk decoration of the uloborid spider *Octonoba sybotides*. Behavioral Ecology 10(5):607-611.

*** UTHSCSA ImageTool Version 3.0 http://compdent.uthscsa.edu/dig/download.html

Received: 30 April 2015. Accepted: 29 May 2015. Published online: 26 June 2015. Authors:

How to cite this article:

Abrenica-Adamat L. R., Catindig Jr. R. C., 2015 Salient features of the orb-webs of the grass cross spider, *Argiope catenulata* (Araneae: Araneidae), ELBA Bioflux 7(1):52-60.

Liza R. Abrenica-Adamat, Department of Biological Sciences, College of Science and Mathematics, Mindanao State University – Iligan Institute of Technology 9200 Iligan City, Philippines, e-mail: lizadamat@gmail.com Rosendo C. Catindig, Jr., Department of Biological Sciences, College of Science and Mathematics, Mindanao State University – Iligan Institute of Technology 9200 Iligan City, Philippines, e-mail: rosendo.ctnd@gmail.com This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution and reproduction in any medium, provided the original author and source are credited.