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RESEARCH NOTE

NOTES ON *CYCLOSA INSULANA* (ARANEAE, ARANEIDAE) OF PAPUA NEW GUINEA

The orb weaver *Cyclosa insulana* (Costa 1834) is one of several species within the families Uloboridae and Araneidae that builds stabilimenta, conspicuous silk structures within the orb. Structures referred to as stabilimenta vary considerably among species, and their functions have been hotly debated. Stabilimenta may serve to attract prey (Craig & Bernard 1990) or camouflage the spider against predators (Edmunds 1986; Nentwig & Rogg 1988; Craig & Bernard 1990; Eberhard 1990; Schoener & Spiller 1992; Kerr 1993; Blackledge 1998b) or startle predators (Schoener & Spiller 1992) (see also Nentwig & Ross (1988) who consider neither prey attraction nor camouflage as important). Stabilimenta may also prevent aerial insects and birds from damaging the web by advertizing the presence of the web (Ewer 1972; Horton 1980; Eisner & Nowicki 1983; Kerr 1993; Blackledge 1998a). Phylogenetic data suggest that stabilimenta have evolved several times (Scharff & Coddington 1997), perhaps serving different functions.

Cyclosa (Menge 1866) species exhibit both circular and linear stabilimenta (Edmunds 1986). Camouflaging (Marson 1947; Edmunds 1986; Neet 1990) and stabilizing (Neet 1990) functions have been suggested for the stabilimenta of some *Cyclosa* species, and Tso (1998) found support for the insect-attraction hypothesis in *Cyclosa conica* (Pallas 1772). Here we describe the characteristics of the linear stabilimentum in a population of *C. insulana* in Papua New Guinea. We provide detailed measurements of web characteristics and a small manipulative test of the aposematic (i.e., ‘‘web advertisement’’) function for stabilimenta. We also compare some unique observations of their mating behavior to those of a previous report (Robinson & Robinson 1980).

Cyclosa insulana ranges from the Mediterranean to Australia. We carried out our field work in Cimbu Province, Papua New Guinea between 20–31 August 1995. Our field site was located at the Wara Sera Research Station, 10 miles northeast of the village of Haia and approximately 2286 m above sea level. We found *C. insulana* under the eaves of two buildings in areas measuring approximately 3 × 20 × 15 m and 2 × 6 × 6 m. We characterized *C. insulana* webs by measuring (1) web diameter from the two widest points (from the top of the orb to bottom), (2) stabilimentum length and by counting (3) the number of radii and sticky spirals of the webs of 39 adult females and juveniles. Adult males were seen only during courtship on the web of a single adult female. The radii and sticky spirals were numerous and tightly woven, so we counted them twice independently and averaged our findings for each web. Webs that were damaged to a point where we could not accurately assess diameter, number of radii and rings or stabilimentum length were not used in our analyses for that character.

Web and stabilimentum.—A summary of web characteristics is found in Table 1. *Cyclosa insulana* from Spain (Neet 1990) and Burma (Marson 1947) produce both linear and circular stabilimenta. In exposed (windy) sites, spiders produced significantly smaller webs with a greater number of circular stabilimenta than in unexposed (calm) sites (Neet 1990). In our study population, *C. insulana* constructed permanent linear stabilimenta, but no circular stabilimenta; and webs were relatively large (Table 1). Our study site was very well protected from wind, so the most parsimonious explanation is that local conditions have inhibited construction of circular stabilimenta.

The linear stabilimentum of *C. insulana* extends through the hub at its midpoint. Like several spiders of the family Uloboridae (Lubin 1986), *C. insulana* place egg sacs and debris, including plant material, exuviae and prey exoskeletons, in the stabilimenta (Table 2). When sitting at the hub, and at the midpoint of the

Table 1.—Web characteristics. Diameter and stabilimentum length (in cm, mean ± SD) are compared to measurements of *Cyclosa insulana* webs in Balearics, Spain (Neet 1990).

		Neet (1990)	
Web characteristics	This study	Windy (n = 22)	Calm (n = 20)
Diameter	17.9 ± 5.1 (n = 37)	14.4 ± 4.47	11.7 ± 3.44
Radii	51 ± 13 (n = 35)		
Rings	53 ± 10 (n = 31)		
Damage (%)	14.7 ± 16.0		
Linear stabilimentum length	9.1 ± 31.6 (n = 39)	2.25 ± 1.87	2.25 ± 1.29

stabilimentum, the spider folds its legs against its body. This makes the spider appear (to our eyes) virtually indistinguishable from the stabilimentum. It seems likely that the stabilimentum in this species serves to conceal the spider from aerial predators (Neet 1990) and perhaps potential prey. Our measurements show spiders to have dramatically longer stabilimenta than previously reported (Neet 1990). Linear stabilimenta are permanent structures, independent of web renewal (Table 1; pers. obs.). So, under consistently calm conditions, where there would be no advantage in switching to circular stabilimenta, linear stabilimenta are expected to grow longer as prey items and exuviae are added over time.

Stabilimenta may serve to advertize the web to birds and large insects (Ewer 1972; Horton 1980; Eisner & Nowicki 1983; Kerr 1993), which might otherwise damage the web. In our study site, there was an abundance of vespid wasps capable of such damage. Stabilimenta that provided a visual contrast with background structures would be particularly effective as a conspicuous warning signal. Webs at our site were oriented perpendicularly to the ground and in between the wooden posts supporting the buildings, thereby possessing vertical or horizontal backgrounds (specific background for a given web could not be assigned since it is dependent on the direction of approach). We assessed stabilimentum orientation (n = 39) using a circular grid held behind the web, and leveled so that the spider was aligned with the grid origin. The grid was comprised of 16 sections, each 15°, and we recorded the sections through which the stabilimentum passed. Some spiders built slightly nonlinear stabilimenta, but all tended toward a horizontal or vertical orientation (Fig. 1). This tendency might be related to the consistent vertical/horizontal background at this site. A comparison with *C. insulana* webs characterized by more variable backgrounds would provide a test of this possibility.

Table 2.—Contents of stabilimenta (n = 10) expressed in terms of the mean number of items found per stabilimentum and the mean proportion of stabilimentum length taken up by items found. Fungi and plant material were estimated only in terms of the proportion of stabilimentum length with fungi and/or plant material.

	Mean number ± SD	Mean proportion of length ± SD
Egg sacs	2.3 ± 2.2	0.24 ± 0.23
Exuviae	2.1 ± 2.0	0.1 ± 0.2
Fungi and/or plant material	n/a	0.1 ± 2.1
Arthropod exoskeletons	4.0 ± 3.0	0.6 ± 0.2
Araneae	0.02 ± 0.63	n/a
Homoptera	0.50 ± 0.85	n/a
Coleoptera	3.0 ± 2.4	n/a
Hemiptera	0.20 ± 0.63	n/a
Diptera	0.20 ± 0.42	n/a
Hymenoptera	0.80 ± 1.14	n/a

On the second day of our study, we noted that 2 of the 39 spiders in our study site changed the orientation of their stabilimenta from vertical to horizontal. We hypothesized that stabilimentum orientation was plastic, and that spiders would switch its orientation if the web incurred sufficient damage on the previous day. To test this hypothesis, we chose 20 webs (10 vertical and 10 horizontal stabilimenta) and damaged them by cutting 1 or 2 guylines so that webs collapsed to approximately ⅔ their original size. Examination of the webs on the following day revealed that

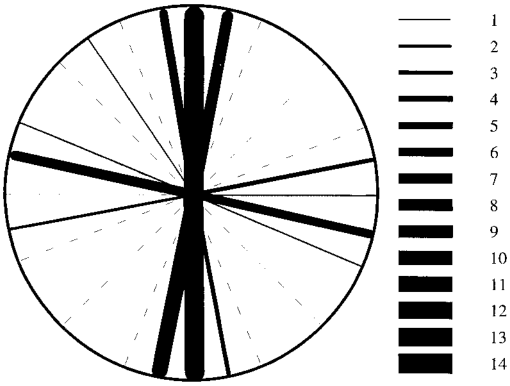

Figure 1.—Stabilimentum orientation. Dashed lines indicate zones on the grid where stabilimenta were marked. Line thickness indicates the relative number of stabilimenta with a particular orientation. Note that several stabilimenta were not perfectly linear, but all tended toward a vertical or horizontal orientation on the web.

none of the stabilimenta orientations had changed, though one was left unrepaired and two spiders had abandoned their location. Thus, it seems that *C. insulana* does not alter stabilimentum orientation in response to web damage. We have no evidence to support the hypothesis that web orientation is manipulated to enhance the conspicuousness of the web against background vegetation. It is possible, however, that the amount of web damage inflicted in our study was not sufficient to evoke this kind of response. A more detailed study involving more extensive and/or different kinds of damage (e.g., to the radii rather than guylines) may provide a better test.

Courtship behavior.—Robinson & Robinson (1980) noted that up to 5 males may congregate on guylines of female's webs where they may court females, rest, or fight and chase other males. The sequence of behaviors exhibited by courting males typically involves (1) the attachment of a mating thread (2) plucking, bobbing, bouncing and high-intensity jerking on the mating thread, (3) and repeated approaches to the female. Female behavior may include (1) no response, (2) approaching the male, (3) plucking the web while facing the male and chasing the male. Contact between the male and female may lead to copulation or rejection of the male by the female (Robinson & Robinson 1980; pers. obs.). Our observations of courtship behaviors, though brief, reveal a male-male competition strategy not previously reported in *C. insulana*.

On 25 August 1995, we observed courtship between 0945–1115 h, although courtship took place before and after our observations. Four males lined the periphery of a single female's web, each on separate guylines. Each male advanced along the guyline, apparently laying down silk. As males approached the hub, they plucked the silk vigorously. In response to plucking, the female oriented to the courting male. If the male continued courting, the female advanced toward him. Sometimes the male was chased off the web before contact. If contact occurred, the female struck at the male, the two grappled, and eventually the male fell off the guyline. Males grappled with the female between 1–10 seconds before falling off the guyline. The entire courtship sequence (plucking, approaching, retreating, grappling, striking, and falling) occurred repeatedly. Once, the female seemed to assume a copulatory position for approximately 5 seconds while the male attempted copulation. Before any palpal insertion was observed, however, the female struck the male with her legs, knocking him off the guyline.

Males occasionally plucked the web simultaneously. On two separate occasions, we noted a male traveling around the web frame to the location of another male. After waiting for the other male to begin plucking, he cut a line of silk, effectively eliminating any direct vibratory transmissions between the courting male and the female. It is possible that cutting the guyline also reduced vibratory transmission to other parts of the web (i.e., to the location of other males around the web). After cutting his competitor's guyline, the male returned to his original position on another guyline, and resumed courting. Throughout the day, damage of this kind reduced web size to approximately 40% of its original size. Silk-cutting behaviors have not been previously reported in *C. insulana*. Rovner (1968) noted severe reduction of the female web by courting females of *Linyphia triangularis* (Clerk). However, it is uncertain if this activity has the same function as in *C. insulana*. Male *L. triangularis* performed the silk-cutting whether or not competitor males were present. These males may have been reducing the potential for future suitor competition, or this action may somehow increase the chances that a female *L. triangularis* will mate.

In addition to this silk-cutting, male-male competition involved plucking silk lines leading to the location of their competitor. On one occasion, an intruding (fifth) male was ‘‘chased’’ away when one of the males plucked the guyline on which he tried to enter the web. These observations are consistent with previous observations of male-male interactions (Robinson & Robinson 1980).

It seems that females have the opportunity to detect signals generated from multiple males. Males apparently compete with other males for access to females by reducing the transmission medium between competing males and the female and perhaps by signalling their status to intruding males. It also seems possible that the opportunity for male choice exists; the quality of the female could be signaled by the mass of the stabilimenta (proportional to the number of prey items and egg sacs present).

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LITERATURE CITED

Blackledge, T.A. 1998a. Signal conflict in spider webs driven by predators and prey. Proc. Roy. Soc. London B., 265:1991–1996.

Blackledge, T.A. 1998b. Stabilimentum variation and foraging success in *Argiope aurantia* and *Argiope trifasciata* (Araneae: Araneidae). J. Zool., 246:21–27.

Craig, C.L. & C.D. Bernard. 1990. Insect attraction to ultraviolet-reflecting spiders and web decorations. Ecology, 71:616–623.

Eberhard, W.G. 1990. Function and phylogeny of spider webs. Ann. Rev. Ecol. Syst., 21:341–372.

Edmunds, J. 1986. The stabilimenta of *Argiope flavipalpis* and *Argiope trifasciata* in West Africa, with a discussion of the function of stabilimenta. Pp. 61–72, *In* Proceedings of the Ninth Intern. Cong. Arachnol., Panama 1983 (W.G. Eberhard, Y. Lubin & B.C. Robinson, eds.). Smithsonian Inst. Press, Washington, D.C.

Eisner, T. & S. Nowicki. 1983. Spider web protection through visual advertisement: role of the stabilimentum. Science, 219:185–187.

Ewer, R.F. 1972. The devices in the web of the West African spider *Argiope flavipalpis*. J. Nat. Hist., 6:159–167.

Horton, C.C. 1980. A defensive function for the stabilimentum of two orb-weaving spiders (Araneae, Aranaeidae). Psyche, 87:12–20.

Kerr, A.M. 1993. Low frequency of stabilimenta in orb webs of *Argiope appensa* (Araneae: Araneidae) from Guam: An indirect effect of an introduced avian predator? Pacific Sci., 47:328–337.

Lubin, Y.D. 1986. Web building and prey capture in the Uloboridae. Pp. 132–171, *In* Spiders: Webs, Behavior and Evolution. (W.A. Shear, ed.). Stanford Univ. Press, Stanford, California.

Marson, J.E. 1947. Some observations on the variations in the camouflage devices used by *Cyclosa insulana* (Costa), an Asiatic spider, in its web. Proc. Zool. Soc. London, 117:219–227.

Neet, C.R. 1990. Function and structural variability of the stabilimenta of *Cyclosa insulana* (Costa) (Araneae, Aranaeidae). Bull. British Arachnol. Soc., 8:161–164.

Nentwig, W. & H. Rogg. 1988. The cross stabilimentum of *Argiope argentata* (Araneae: Araneidae) -nonfunctional or nonspecific stress reaction. Zool. Anz., 221:248–266.

Robinson, M.H. & B. Robinson. 1980. Comparative studies of the courtship and mating behavior of tropical araneid spiders. Allen Press, Inc., Lawrence, Kansas.

Scharff, N. & J.A. Coddington. 1997. A phylogenetic analysis of the orb-weaving spider family Araneidae (Arachnida, Araneae). Zool. J. Linn. Soc., 120:355–434.

Schoener, T.W. & D.A. Spiller. 1992. Stabilimenta characteristics of the spider *Argiope argentata* on small islands -support of the predator-defense hypothesis. Behav. Ecol. Sociobiol., 31:309–318.

Tso, I.M. 1998. Stabilimentum-decorated webs spun by *Cyclosa conica* (Araneae, Araneidae) trapped more insects than undecorated webs. J. Arachnol., 26:101–105.

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