TRANSITION FROM PREDATORY JUVENILE MALE TO MATE-SEARCHING ADULT IN THE ORB-WEAVING SPIDER *NEPHILA CLAVIPES* (ARANEAE, ARANEIDAE)

Behavioral strategies of male orb-weaving spiders change rather dramatically as they mature to adulthood. Juvenile males are sedentary predators, capturing prey on webs of their own construction. However, upon reaching adulthood, they shift to a search strategy, approaching females who usually inhabit solitary webs

(Robinson 1982). As pronounced as these changes are, few field data have been gathered on marked, unrestrained juvenile males as they mature to adulthood. The purpose of this study is to provide ethological descriptions of this transition phase in the life cycle of *Nephila clavipes*, a New World orb-weaver. Specifically, we describe web maintenance, changes in body coloration and size, sperm web construction, sperm transfer to the palps, and dispersal as males mature from the penultimate instar to adulthood.

Forty-one juvenile males in the penultimate instar were observed from the second week in July to the last week in August, 1984 at the F. Edward Herbert Center of Tulane University, located about 20 km south of New Orleans, Louisiana. Criteria for inclusion were that the male must have been residing on a male-constructed web, and there had to be evidence of the final molt during the course of observation. These criteria were met by 28 males.

A census of the males was taken every morning between 0800 and 1000 h. For individual identification, each was marked on the dorsum of the abdomen with fast-drying acrylic paint. Data collected include: estimated amount of viscid spiral in good repair, number of sperm webs, abdominal coloration, and occurrence of molt. The day of the molt was determined by the absence of a paint mark on a recently molted male inhabiting an identified web and/or the presence of a paint-marked exoskeleton. Subjects were re-marked after molting and checked daily until they abandoned the web. The adjacent forest area was searched daily for marked males.

To quantify the change in size occurring at the final molt, we examined eight unrestrained, unmarked males found outside of the census area who had just molted to adulthood. The exoskeleton as well as a front leg (I) were removed and the tibia-patella length of the leg and corresponding portion of the exoskeleton was measured (following Vollrath 1983). For comparison, legs and exoskeletons of 17 females maturing to adulthood were measured in a similar manner.

By the day of the final molt, males had allowed their viscid spirals to almost totally deteriorate (Table 1), as do females at the final molt (Christenson et al. 1985). However, males did not construct a stabilimentum on the final web, as do females (Robinson and Robinson 1973).

The length of the tibia-patella portion of the male front leg increased by 21.5% (SD = 8.8) from the penultimate to the final instar. This was significantly less than the rate of growth for maturing females (35.8%, SD 10.2; $F = 11.445$, df 1,23, $p = 0.003$).

Males built their first sperm web an average of 2.1 days (SD = 0.55) after molting. The typical sperm web was trapezoidal, about 5 × 5 mm in size, and located in the barrier strands or remains of the viscid spiral. Two males were observed constructing sperm webs. First, they moved the abdomen back and forth between what appeared to be already established silk strands, for 150 s in one case and 270 s in the other. To the unaided eye, the resulting web appeared as a dense mat of fine strands. The genital opening was then moved against the web with one male bouncing and the other pushing the ventral abdomen onto the web. Sperm deposition took 75 and 60 seconds. Very quickly thereafter the males began dipping the palps onto the web with the conductor held parallel to the web plane. They were dipped in a mostly alternating manner, once every two seconds, for 105 and 135 seconds. Microscopic examination of ten sperm webs revealed

Table 1.—Census data relating to condition of the viscid spiral and presence of sperm webs on the orbs of male *N. clavipes* gathered during a ten day period around the time of their final molt.

Day	*N*	% of Viscid Spiral Intact		% of Orbs with Sperm Webs	Of Orbs with Sperm Webs, $\bar{X}$ Number Present	Range of Sperm Webs
		>90%	<10%			
PRE-MOLT						
5	17	0.94	0.06	0	—	—
4	19	0.89	0.11	0	—	—
3	21	0.52	0.34	0	—	—
2	25	0.40	0.36	0	—	—
1	25	0.12	0.79	0	—	—
Molt	28	0.04	0.93	0	—	—
POST-MOLT						
1	25	0.00	1.0	12.0	1.0	1-1
2	19	0.00	1.0	68.4	2.2	1-5
3	8	0.00	1.0	75.0	1.5	1-2
4	3	0.00	1.0	100.0	2.0	1-3

the strands to be loose and tangled in appearance. Transfer to the palps must be quite efficient because only one web contained sperm, and it had only one sperm.

Frequently, we found several sperm webs on a given orb (Table 1). Unfortunately, it was not possible to accurately determine the total number of sperm webs constructed by a given male. They were damaged by wind and rain and thus nearly impossible to individually recognize from day to day.

During this time male color is changing. Typical abdomen coloration of the juvenile male was female-like, yellow/caramel and white (see Levi 1980). In the penultimate instar, palps and femurs were a translucent light grey. However, on the day after the final molt, abdomen coloration was darker for half of the subjects, palps darker in all males, and femurs darker in 86%. By the third day, 20% of the males had the typical adult abdominal coloration, a uniform dark caramel or copper. The black midline stripe and the black elongated marks lateral to posterior abdomen, prominent in juveniles, were visible but relatively faint. Adult coloration was complete in about one week. These color changes were more pronounced than those of the female, for they maintain the yellow juvenile coloration.

Robinson and Robinson (1976) noted that the functions of maturational color changes are not clear. It is possible that the relatively dark color of the male serves as camouflage while moving on branches or twigs when between female webs. Predatory pressure on moving males is thought to be relatively high (Christenson & Goist 1979; Vollrath 1980). Whatever their significances, changes in coloration are indispensible in estimating male age.

Males abandoned the web an average of three days (SD = 0.74) after molting and an average of one day (SD = 0.74) after appearance of the first sperm web. Eight of our 28 males were found on female webs, six with a juvenile female and two with a female who had just molted. It should be noted that most females in the immediate area were juveniles. Only one male had moved to the nearest female; their webs were already connected.

Although mating occurs on the female's web, sperm webs are infrequently found there. In July, out of a total of 770 census-days of marked males on female

webs, only seven sperm webs were noted. Census data gathered in a similar manner in 1982 indicated 17 sperm webs on female orbs in a total of 628 marked male-days. In three of these cases, the male present did not yet have the adult coloration and probably had not had the opportunity to build sperm webs on its own orb prior to abandonment. The failure of sperm webs to appear after mating is consistent with the observation that male *N. clavipes* deplete their sperms stores after mating with a female just after her final molt and do not produce more sperm (Manuscript in preparation).

We thank J. Coddington, A. Rypstra, and B. Robinson for their comments. This study was funded by NSF grant BNS-8317988 to the second author.

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Manuscript received April 1987, revised November 1987.