

# **ELECTRONIC APPENDIX**

This is the Electronic Appendix to the article  
**Babes in the wood – a unique window into sea scorpion ontogeny**

by

James C. Lamsdell and Paul A. Selden

Comprising the morphological character list and character matrix used in the  
phylogenetic analysis

## Character list

1. Angular projection on the anterior of the carapace: absent (0); present (1).
2. Anterior margin of carapace: unornamented (0); denticulate (1).
3. Carapace marginal rim: present (0); absent (1).
4. Carapace genal spines: present (0); absent (1).
5. Carapace shape: horseshoe or wide-horseshoe (0); semicircular (1); quadrate (2); trapezoidal (3); wide-rectangular (4); subquadrate (5); campanulate (6); parabolic (7); spatulate (8); triangular (9); long-rectangular (10).
6. Carapace genal facets: absent (0); present (1).
7. Angle of genal facets: low angle (0); high angle (1).
8. Lateral eye shape: crescentic (0); expanded (1).
9. Size of palpebral lobe: small (0); large (1); absent (2).
10. Lateral eye position: centrilateral (0); centrimesial (1); antelateral (2); central (3); antemesial (4).
11. Lateral eye abuts carapace margin: absent (0); present (1).
12. Lateral eyes associated with ophthalmic ridge: present (0); absent (1).
13. Suture on ventral plates: *Eurypterus*-type (0); *Hughmilleria*- or *Hallipterus*-type (1); *Megalograptus*-type (2); *Erieopterus*-type (3).
14. Transverse suture on ventral plates: present (0); absent (1).
15. Chelicerae: small (0); able to extend beyond marginal rim (1).
16. Form of cheliceral peduncle: approximately equal in length to fixed ramus (0); longer than fixed ramus (1).

17. Denticles on chela: absent (0); present, small, undifferentiated (1); present, large, differentiated (2).
18. Largest denticle medially on fixed ramus: erect (0); inclined (1); acute (2).
19. Angular distal teeth on both rami: absent (0); present (1).
20. Relative lengths of appendages II-V: increasing posteriorly (0); forward appendages enlarged (1).
21. Morphology of spines on prosomal appendages II-IV: reduced [length < width of podomere] (0); regular [length  $\approx$  width of podomere] (1); enlarged [length > width of podomere] (2); absent (3).
22. Mobility of spines on appendages II-V: fixed (0); moveable (1).
23. Orientation of spines on appendages II-V: ventral (0); anterior (1).
24. Spines on appendages II-V: thickened and highly sclerotised absent (0); present (1).
25. Armature of anterior prosomal appendages flattened and laterally expanded into blades: absent (0); present (1).
26. Prosomal appendage podomeres thicken distally: absent (0); present (1).
27. Morphology of appendage V podomeres: undifferentiated and broad (0); podomeres tubular, lacking armature except for penultimate distal podomere (1).
28. Appendage V armature: non-spiniferous (0); spiniferous (1).
29. Coxal lade: absent (0); present (1).
30. Morphology of prosomal appendage VI: equal in width along length (0); distally expanded into swimming leg (1).
31. First podomere of prosomal appendage VI that fully projects beyond carapace margin: Fourth podomere (0); Sixth podomere (1); Third podomere (2).

32. Shape of proximal podomere of appendage VI: narrow [ $L/W \geq 2.0$ ] (0); expanded [ $L/W < 2.0$ ] (1).
33. Anterior margin of coxa VI undifferentiated (0); expanded to form 'ear' (1).
34. Shape of 'ear' on coxa VI: triangular (0); rectangular (1); subquadrate/semicircular (2).
35. Anterior denticle of coxa VI large: absent (0); present (1).
36. Angle between VI-3 and VI-4:  $180^\circ$  (0); not  $180^\circ$  (1).
37. Length of podomeres VI-4 and VI-5:  $VI-5 > VI-4$  (0);  $VI-4 \geq VI-5$  (1).
38. Length of podomeres VI-4 when VI-5 is not longer:  $>VI-3$  and VI-5 (0); equal to VI-3 and VI-5 (1).
39. Podomere VI-5 bordering podomere VI-7: absent (0); present (1).
40. Distal podomere margin of VI-6 modified: absent (0); present (1).
41. VI-7 lateral margins: unornamented (0); enlarged serrations (1); small serrations (2).
42. Angular projection on the anterior of podomere VI-7: absent (0); present (1).
43. Podomere 7a on appendage VI: absent (0); present on posterior of appendage (1); present on anterior of appendage (2).
44. Width of posterior VI-7a: narrow [less than 50% width of VI-7] (0); wide [more than 50%] (1).
45. Shape of posterior VI-7a: oval (0); triangular (1).
46. VI-8 lateral margins: unornamented (0); small serrations (1); enlarged serrations (2).
47. VI-8 anterior projection: absent (0); present (1).
48. Additional moveable lobe on VI-8: absent (0); present (1).
49. Morphology of VI-8/VI-9 joint: joint flush (0); VI-9 set into VI-8 (1).

50. Length of VI-9 (as ratio of VI-8): large [ $>25\%$  of VI-8 length] (0); small [ $<25\%$  of VI-8 length] (1); totally absent (2).
51. Shape of podomere VI-9: spinose (0); triangular, pentagonal or oval (1).
52. VI-9 margin: no ornament (0); serrated (1).
53. VI-9 position: centrally on podomere 8 (0); migrating towards posterior of podomere 8 (1).
54. VI-9 expanded: absent (0); present (1).
55. Podomere cuticular morphology: rounded (0); ridged (1).
56. Metastoma anterior: smooth or shallow notch (0); deeply notched (1).
57. Shape of posterior margin of metastoma: rounded (0); truncated/flattened (1); angular (2); notched (3).
58. Metastoma with posterior median cleft: absent (0); present (1).
59. Metastoma shape: broad (0); petaloid, markedly narrower in width (1).
60. First segment expressed dorsally: expressed (0); folded under carapace (1).
61. Microtergite: absent (0); present (1).
62. Genital operculum morphology: consisting of three visible segments (0); consisting of two visible segments (1); unfused (2).
63. Morphology of anterior opercular plate: fully expressed (0); lateral expression only (1); completely suppressed (2).
64. Thickness of anterior opercular plate: fully expressed (0); narrow (1).
65. MOP and POP morphology: separate/with clear suture (0); without suture but with ornament differentiation (1); without suture and without ornament differentiation (2).

66. Unsegmented genital appendages: absent (0); present (1).
67. Type-A genital appendage spoon-shaped: absent (0); present (1).
68. Type-A genital appendage with median, distal indentation: absent (0); present (1).
69. Type-B genital appendage oval: absent (0); present (1).
70. Morphology of type A genital appendage furca: fused (0); unfused (1).
71. Spatulae on type A genital appendage: absent (0); present (1).
72. Morphology of spatulae: angular (0); rounded (1).
73. Moveable preabdominal spines: absent (0); present (1).
74. Postabdominal epimera: present (0); absent (1).
75. Preabdominal/postabdominal boundary: between 7th and 8th segments (0); between 6th and 7th segments (1); between 4th and 5th segments (2).
76. Epimera on segment 7: absent (0); present (1).
77. Number of segments in postabdomen: 3 (0); 5 or 6 (1); 9 (2).
78. Postabdomen: undifferentiated (0); narrowing from preabdomen (1).
79. Caudal postabdoment: absent (0); present (1).
80. Posterior margin of all opisthosomal tergites crenulate: absent (0); present (1).
81. Posterior margin of segments 7-9: smooth (0); dentate (1).
82. Posterior margin of segments 10-12: smooth (0); dentate (1).
83. Epimera on pretelson: absent (0); angular (1); rounded (2); quadrate (3).
84. Laterally expanded pretelson: absent (0); present (1).
85. Median carina on pretelson: absent (0); present (1).
86. Telson shape: straight (0); curved (1); laterally expanded (2).
87. Laterally expanded telson shape: rounded (0); triangular (1).

88. Telson base: flattened (0); bulbous expansion (1).
89. Telson bilobed: absent (0); present (1).
90. Median carina on telson: absent (0); low carina (1); vertical rudder (2).
91. Telson laterally ornamented with scales: absent (0); present (1).
92. Telson margin: smooth (0); serrated (1).
93. Opisthosoma lateral division: none (0); trilobed (1).
94. Primary opisthosomal ornamentation: scales (0); closely spaced pustules (1); coarse pustules (2).
95. Primary carapace ornamentation: scales (0); closely spaced pustules (1); coarse pustules (2).
96. Principal scale on carapace: absent (0); present (1).
97. Carapace ornament including elongate pustules that angle away from the lateral eyes and curve around the carapace margin: absent (0); present (1).
98. Row of node-like scales on dorsal opisthosomal segments: absent (0); present (1).
99. Ornamentation of angular scales across posterior of tergite segments: absent (0); present (1).
100. Longitudinal rows of angular scales on tergites: absent (0); present (1).
101. Ornament of chevron scales: absent (0); present (1).
102. Ornament of linguoid scales: absent (0); present (1).
103. Form of posterior margin of articulating facet on tergites: row of pustules (0); row of scales (1); groove (2).

104. Genital operculum striate ornament marked by highly sclerotised, broad lunate scales: ornament independent of sclerotised scales (0); ornament congruent with broad, sclerotised lunate scales (1).



### Character matrix (main analysis)

(A = [0,1]; B = [1,2])

Taxon	10	20	30	40	50	60	70	80	90	100												
<i>Weinbergina opitzi</i>	00100	0-0-?	00310	00--0	11000	00000	010-0	00-00	000--	00000	00000	---0	022-0	-----	--000	00000	00000	0-000	00011	00000	0000	
<i>Chasmataspis laurencii</i>	00000	0-101	01???	?????	?????	0???	?00-0	00-00	000--	000--	---0	?????	1????	?????	??002	02110	00000	0-000	00122	00100	00??	
<i>Octoberaspis ushakovi</i>	00003	0-000	00???	?????	?????	000?1	0????	???	002--	00002	---0	02000	12000	00010	0-002	02100	00100	0-000	00022	00000	00??	
<i>Diploaspis casteri</i>	00003	0-100	001??	?????	00000	0???	0????	???	002--	00002	---0	?????	1200?	?????	??002	02100	00000	20000	01022	00100	00??	
<i>Loganamarpis dunlopi</i>	00003	0-?0?	??310	00--?	?????	0???	000-?	0????	?????	?????	?????	02000	12000	000?0	0-012	02100	00000	0-?00	0?0--	-0000	00??	
<i>Brachyopterus stubblefieldi</i>	00018	0-001	01?0?	?????	00000	000?0	000-?	00-00	000--	00000	00001	0???	0????	0????	??0?0	01000	00000	0-000	000--	-0000	00??	
<i>Rhenopterus diensti</i>	00017	0-001	01000	00--0	00000	00000	000-0	00-00	000--	00000	00001	00001	00000	0???	0-001	01110	00000	1-000	00000	00000	0000	
<i>Parastylonurus ornatus</i>	00010	0-000	01000	00--0	11000	00000	200-0	00-00	000--	00000	00000	11011	00000	00000	10000	01101	00100	0-001	00000	00000	00?0	
<i>Laurieipterus elegans</i>	01018	0-000	0110?	?????	10000	00000	200-0	00-00	000--	000??	?????	1100?	0????	?????	??0??	?????	?????	?????	?????	??000	00000	00?0
<i>Kokomopterus longicaudatus</i>	00015	0-001	01???	?????	11000	10100	000-0	00-00	000--	00000	00000	1100?	0????	?????	??010	01101	00000	0-000	00111	00000	01?0	
<i>Hardieopterus macrophthalmus</i>	00010	0-001	01000	00--0	?????	10100	000-0	00-00	000--	00000	00000	1100?	0????	?????	??000	01101	00300	0-000	00111	00000	01?0	
<i>Drepanopterus pentlandicus</i>	00010	10001	01000	00--0	1A001	10000	000-0	00-00	000--	00000	00000	11101	00000	?001?	10010	01100	00000	0-000	00011	00000	0000	
<i>Hibbertopterus scouleri</i>	00010	11003	01000	00--0	2A001	10010	000-0	00-00	000--	000??	?????	1110?	0????	?????	??010	01001	00000	0-000	00000	00000	01?0	
<i>Megarachne servinei</i>	00013	0-003	01???	?????	2A001	1001?	?00-0	?????	?????	?????	?????	?????	0????	?????	?????	?????	?????	?????	?????	??000	00???	????
<i>Stoermeropterus conicus</i>	00010	0-001	01110	00--0	00000	00000	01100	00-00	00100	00000	00001	10001	00010	00010	10100	01000	01B00	0-100	00011	00000	0000	
<i>Stoermeropterus latus</i>	00010	0-001	01110	00--?	?????	0???	0???	00-00	00100	00000	00001	?????	00010	000??	11100	01000	01100	0-100	00000	00000	00?0	
<i>Stoermeropterus nodosus</i>	00010	0-001	01???	?????	?????	0???	?????	?????	?????	?????	?????	10001	00010	000?0	11100	01000	0?200	0-100	00011	00100	00??	

<i>Vinetoferus struvei</i>	01010	0-001	01310	00--0	00000	00000	01100	00-00	00100	00000	00001	00001	00010	0??1?	??000	01100	11000	0-?00	00011	00100	0000
<i>Vinetoferus martini</i>	01010	0-?01	0131?	?????	00000	00000	0????	00-00	00100	00000	00001	????1	0????	?????	??000	01100	11000	0-?00	00011	00100	00??
<i>Moselopterus ancylotelson</i>	00010	0-001	01310	00--0	10000	00000	01100	00-00	00100	00000	00001	00001	00010	0001?	10010	01100	11000	1-000	01011	00100	0000
<i>Moselopterus elongatus</i>	00010	0-001	01310	00--0	10000	00000	01100	00-00	00100	00000	00001	00001	00010	?????	??010	01100	11000	1-000	01011	00?00	0000
<i>Onychopterella augusti</i>	00015	0-?01	01???	?????	11000	0??01	01100	00-00	00101	00010	00000	?????	0????	?????	0-000	01100	00000	0-100	00000	0?000	00??
<i>Onychopterella kokomoensis</i>	00015	0-101	01310	00--0	11000	00101	01???	00-00	00101	00010	00000	00001	00010	000?1	0-000	01100	00200	0-100	00000	0?000	00?0
<i>Dolichoferus macrocheirus</i>	00012	0-012	01010	00--0	21000	00101	01110	11001	11101	20110	11010	11011	00110	000?0	10000	01100	00100	0-000	00000	00000	0000
<i>Euryferus remipes</i>	00013	10101	01010	00--0	11000	01101	01120	01001	00111	10011	10000	00001	00110	00001	0-010	01100	00000	0-000	01000	10011	0010
<i>Hughmilleria socialis</i>	00017	0-122	11111	00--0	11000	00101	01120	01101	00111	00011	10100	0100?	012-2	00010	0-010	11100	00000	0-000	00000	00000	11?0
<i>Tyloferella boylei</i>	00015	0-101	01???	?????	?????	?????	?????	?????	?????	?????	?????	?????	0????	?????	??001	01100	00000	0-000	00000	00000	00??
<i>Megalograptus ohioensis</i>	01012	10104	01210	00--1	21110	01101	01120	01001	00111	00012	---0	03001	012-1	00000	0-011	01100	00000	0-000	00100	00011	0010
<i>Mixopterus kiaeri</i>	00012	10104	01?10	00--1	21110	00101	01120	01111	00111	00011	10000	0000?	012-2	000?0	0-010	01110	00000	1-000	00100	00000	00?0
<i>Strobilopterus laticeps</i>	00011	0-011	01???	?????	?????	?????	1????	01101	00111	00-11	10000	1101?	?0110	000?0	10???	?????	?????	?????	?????	0????	???
<i>Strobilopterus princetonii</i>	00011	10013	01???	00--0	10000	0??01	11120	01101	10111	20110	11000	1?01?	0???	000?0	10000	11100	00000	?????	??011	0?0?0	0001
<i>Strobilopterus richardsoni</i>	00011	0-013	0131?	?????	?????	?????	?????	?????	10111	20011	10000	?????	?????	?????	?????	?????	?????	?????	??011	010??	00??
<i>Strobilopterus proteus</i>	00011	10013	0131?	?????	10000	00101	111?0	01101	10111	20110	11000	1001?	0???	00010	10000	11100	00000	?????	??011	01010	0001
<i>Buffalopterus pustulosus</i>	00011	0-011	0131?	?????	?????	?????	1????	?????	?????	?????	?????	?????	00110	000??	0-000	01100	00100	20000	01011	01010	0000
<i>Erieopterus microphthalmus</i>	00014	11001	01310	00--0	10000	01101	01120	01001	00111	00011	00000	01001	00110	000?1	0-010	01100	00100	1-000	00000	00000	00?0
<i>Paraerypterus anatoliensis</i>	00012	10011	01?1?	?????	11000	0???	0???	010??	?????	?????	?????	?????	0???	?????	??0?0	0???	?????	?????	??001	00010	001?
<i>Pentlandopterus minor</i>	00012	10011	01???	?????	?????	?????	0???	010??	?????	?????	?????	?????	0???	?????	??010	01100	00000	0-000	00011	00000	000?
<i>Dolichoferus jewetti</i>	00012	0-012	0???	00--0	21000	00101	01110	11001	11101	20110	11010	11001	00110	000?0	10000	01100	00100	0-000	00001	00?00	0000
<i>Ruedemannipterus stylonuroides</i>	10016	0-012	01???	?????	?????	?????	0???	11001	?1101	?0110	10110	?????	0???	?????	??0??	?????	?????	?????	??011	00000	00??
<i>Clarkeipterus testudineus</i>	10002	0-012	01???	?????	?????	?????	0???	11001	?1101	?0?10	10010	?????	?????	?????	?????	?????	?????	?????	?????	00?00	????



**Character matrix addition (juvenile instars)**

<b>Instar</b>	<b>10</b>	<b>20</b>	<b>30</b>	<b>40</b>	<b>50</b>	<b>60</b>	<b>70</b>	<b>80</b>	<b>90</b>	<b>100</b>											
<i>Strobilopterus proteus</i> α	00001	0-011	0131?	????0	10000	0010?	011?0	0110?	?????	?????	????0	1001?	0????	000?0	10000	11100	00000	?????	??011	00000	000?
<i>Strobilopterus proteus</i> β	00011	10013	01???	????0	10000	0??01	011??	01101	?????	?????	????0	?????	0????	?????	??000	11100	00000	?????	??011	00000	000?
<i>Strobilopterus princetonii</i> γ	00011	10013	01???	????0	10000	0???1	1????	??01	10111	10011	10000	?????	0????	?????	??000	11100	00000	?????	??011	0?0?0	000?