10.1071/IS14044_AC

Invertebrate Systematics **29**, 239–286.

SUPPLEMENTARY MATERIAL

The evolutionary history of *Lipsothrix* Loew (Diptera: Tipuloidea) inferred through systematic revision and historical biogeographical analysis

Matthew Petersen
Roanoke College, Biology Department, 221 College Lane, Salem, VA 24153, USA. Email: mpetersen13@gmail.com

Table S1. Character list used the 'Key to the world species of *Lipsothrix* Loew (Tipulidae) version 1.0'.

Character: Character state
01. Biogeographic Region: Eastern Nearctic
02. Biogeographic Region: Eastern Palearctic
03. Biogeographic Region: Oriental
04. Biogeographic Region: Neotropical
05. Biogeographic Region: Western Nearctic
06. Biogeographic Region: Western Palearctic
07. Antennae: Male Antennae: flagellomeres elongate, length greater than 4x width; generally resulting in antennae reaching wing when bent backwards
08. Antennae: Male Antennae: flagellomeres not elongate, typically with length less than 3x width; when bent backwards rarely exceed the wing base
09. Antennae: Terminal Flagellomere (Male): small, length less than 1/4 penultimate flagellomere
10. Antennae: Terminal Flagellomere (Male): subequal to about 1/3 the length of the penultimate flagellomere
11. Thorax: Dorsomedial Pronotum Coloration: testaceous-brown-black (may be lighter laterally)
12. Thorax: Dorsomedial Pronotum Coloration: white-yellow-amber
13. Thorax: Dorsal Coloration of Prescutum/Scutum: brown-black; scutum may be lighter in coloration laterally and appearing as dark stripes
14. Thorax: Dorsal Coloration of Prescutum/Scutum: white-yellow-amber; coloration similar to lateral scutum
15. Thorax: Form of Dorsal Coloration of Prescutum/Scutum: present as a distinct dorsal dark stripe, may be medially divided into 2-4 distinct stripes
16. Thorax: Form of Dorsal Coloration of Prescutum/Scutum: uniform across the scutum; may fade laterally but not as distinct stripes
17. Thorax: Base Coloration of Lateral Thorax (Anepisternum, Katepisternum, Anepimeron): uniform brown - black
18. Thorax: Base Coloration of Lateral Thorax (Anepisternum, Katepisternum, Anepimeron): base coloration white - yellow - amber (may be spots of darker coloration present)
20. Wing: Basal Wing Vein R5: greater than the length of M1+2 and r-m combined
21. Wing: Placement of wing crossvein R2: after split of R5; R2+3 shorter than R3
22. Wing: Placement of wing crossvein R2: at or very near split of R4
23. Wing: Placement of wing crossvein R2: beyond split of R5; R2+3 subequal to R3
24. Wing: Wing cell dm: absent
25. Wing: Wing cell dm: present
26. Wing: Shape of cell dm: elongate rectangular; width about 3x height
27. Wing: Shape of cell dm: rectangular - width about twice height
28. Wing: Shape of cell dm: square - width and height subequal

38. Wing: Coloration of Wing (excluding the pterostigma): wing suffused yellow without additional coloration
39. Wing: Coloration of Wing (excluding the pterostigma): wing suffused with darker coloration
40. Wing: Coloration of Wing (excluding the pterostigma): base color variable, but with distinct darker coloration restricted to crossveins and/or cord
41. Wing: Setation along wing vein Sc: absent
42. Wing: Setation along wing vein Sc: present
43. Abdomen: Abdominal Coloration: tergites 1-6 uniform; white - yellow - amber
44. Abdomen: Abdominal Coloration: tergites 1-6 medially brown-black but with lateral edges lighter
45. Abdomen: Abdominal Coloration: tergites 1-6 yellow-amber, with distal edges of tergites and sternites ringed with darker coloration
46. Abdomen: Abdominal Coloration: tergites 1-6 uniformly brown - black (may be darker along posterior edge)
47. Leg: Femur Coloration: uniform white - yellow - amber
48. Leg: Femur Coloration: white - yellow - amber tipped or ringed with darker coloration
49.. Leg: Femur Coloration: uniform brown - black
50. Leg: Femur Coloration: base narrowly amber- yellow, remainder broadly brown - black
51. Leg: Tibia Coloration: uniform white - yellow - amber
52. Leg: Tibia Coloration: white - yellow - amber tipped or ringed with darker coloration
53. Leg: Tibia Coloration: uniform brown - black
54. Leg: Tarsomeres: similar in coloration to tibia; not white
55. Leg: Tarsomeres: abruptly white
56. Leg: Tarsal Claws (Male): toothed; typically with more than one large tooth (2-4 teeth)
57. Leg: Tarsal Claws (Male): untoothed; typically a single tooth placed basally (0-1 teeth)
58. Male Hypopygium: Number of Terminal Aedeagal Branches: one
59. Male Hypopygium: Number of Terminal Aedeagal Branches: two
60. Male Hypopygium: Aedeagus Orientation: directed posteriorly, generally straight
61. Male Hypopygium: Aedeagus Orientation: directed ventrally; apex may be directed in a posterior, anterior or dorsal direction
62. Male Hypopygium: Basal Lobe of Interbase: enlarged as a compressed peak
63. Male Hypopygium: Basal Lobe of Interbase: enlarged, dorsal edge typically with a small ridges (scalloping)
64. Male Hypopygium: Basal Lobe of Interbase: not greatly enlarged
65. Male Hypopygium: Dorsal Lobe of Aedeagus: absent
66. Male Hypopygium: Dorsal Lobe of Aedeagus: present; lobe height greater than that of width of aedeagus
67. Male Hypopygium: Interbase: no small spines along the length of interbase
68. Male Hypopygium: Interbase: series of small spines present along the length of interbase
69. Male Hypopygium: Ventral Lobe of Aedeagus: absent
70. Male Hypopygium: Ventral Lobe of Aedeagus: present; lobe height greater than 1/2 width of aedeagus

Table S2. Character matrix used the 'Key to the world species of *Lipsothrix* Loew (Tipulidae) version 1.0'.

Species	Characters
	0000000001111111111222222222233333333334444444444555555555566666666667
	1234567890123456789012345678901234567890123456789012345678901234567890
L. apicifusca	2122220101010100011000101100101010101000221000210021010011001001101010
L. assamica	2212220101010100011001010000101010101000102102120033310010101001101001
L. babai	2122220101101001101221001120011201102010010001001000110121001010101010
L. burmica	2212220101101001101001001010101010100010100010010001100133333333333333
L. chettri	2112220101100100011001001001101010102100103333210021010010101001331033
L. decurvata	2122220110101010211010001021101010010010100001010001010010101001011010
L. ecucullata	2222210101010100011011001010101010101000011000010001010101010001101021
L. errans	2222210101010100011010001210101010101000011000010001010101001001011010
L. fenderi	2222120101010100011000101100101010101000101000010001010101001001101010
L. flavissima	2212220110010100011001001010101010101001001000012100210100101010010110 10
L. heitfeldi	2122222110101001101010001010101010100010010001010001010013333033031033
L. hynesiana	2222121010100010011000100000101010210001010001100010010101001001101010
L. kashmirica	2212220101010100011012001010101010101000010100010001010101001100100121
L. kraussiana	2212223333011111011001001001101010010001100010010001010010101001011010
L. leucopeza	2122220101121201010110001100100110102010101001100010011011001001101010
L. malla	2212221210101010011001001010101010121010100102000001010010101001011010
L. mirabilis	2122220101101012101000101100101010120001010001000100110101001001101010
L. neotropica	2221220101010100011010000010011010101000101000100010011011001001101010
L. nervosa	2222211001101010011010001010101010012010010201010201010101001001101001
L. nigrilinea	2222120101101011101100100121012120110001001010001000011010100101010101 0
L. nobilis iranica	2122220100101010011010001010101010012000010101010012010101001001101001
L. nobilis nobilis	2222210101101000011010001010101010010001010101010012010101001001101001
L. nullusarma	2212220101333333331010001010101010101000010100010001010101001100101021
L. orthotenes	2112220101210100010110001210101010101010101002210021010010101001311031
L. pluto	2122221021101001101020101100101010010010010001000100110101001021101010
L. propatula	2112220101101011101010010000101010212010100001010001010013333333333333
L. remota	2222210101010100011010001010101010101100011000100010010101001001101001
L. shasta	2222120101101001011001001120101201102010012102010001010101001010101010
L. sylvia	1222220101101001011210001010101010011000010102010001010011001010101010
L. taiwanica	2212220101331010012110201120101010102010101000100210001011001001101010
L. tokunagai	2122220101010100011010001010211210102100011000100010011101001001101010
L. yakushimae	2122223333101001100110101100101010100010100001001000101013333333333333
L. yamamotoana	2122220101101001101010001120101010012010010001010001010101001001511001

Table S3. Character matrix of 45 discrete binary and non-ordered multi-state coded characters derived from immature and adult morphological characters.

Number	Character: Character States
1.	**Number of larval spiracular lobes:** (0) Five; (1) Four; (2) Absent.
2.	**Larval anal papillae divided by constrictions:** (0) Absent; (1) Present.
3.	**One or more rows of spines along posterior margin of the pupal abdominal segments:** (0) Present; (1) Absent.
4.	**Larvae with dorsal creeping welts:** (0) Absent; (1) Present.
5.	**Ventral parameres joined medially below the aedeagus with a ventral projection:** (0) Absent; (1) Present (Fig. 7).
6.	**Dorsal parameres directed dorsally from aedeagal complex, medially concave with length greater than width:** (0) Absent, or dorsal parameres not presented as described; (1) Present (Figs 4-7).
7.	**Position of sperm sac:** (0) Anterior to dorsal parameres; (1) Ventral to and in directed alignment with the dorsal parameres (Fig 4).
8.	**Gonostylus:** (0) Bifid; (1) Singular.
9.	**Tooth of outer gonostylus:** (0) Absent; (1) Present, placed medially to near the distal end of the style (Figs 44-69).
10.	**Multiple rasp-like teeth along the distal edge of the outer gonostylus:** (0) Absent; (1) Present.
11.	**Posterior edge of 9th tergite:** (0) Simple; (1) Produced into two elongate lobes.
12.	**Elongation of male flagellomeres:** (0) Absent, length subequal to < 4x width; (1) Present, length greater than 5x flagellomere width.
13.	**Terminal flagellomere:** (0) Subequal to ½ the length of penultimate flagellomere; (1) Length reduced to less than 1/5 the penultimate flagellomere.
14.	**Pruinosity of male flagellomeres:** (0) Sparse or weakly present; (1) Strongly present, length of setae often subequal to width of the flagellomere.
15.	**Macrotrichia present in apical (Radial and Medial) wing cells:** (0) Absent; (1) Present (Figs 14).
16.	**Macrotrichia present along wing vein Sc:** (0) Absent; (1) Present.
17.	**Wing vein Sc_2 removed from vein Sc1, Sc2 longer than Sc_1:** (0) Absent; (1) Present (Fig 33).
18.	**Wing vein Sc_1 removed from vein Sc2, Sc1 longer than Sc_2:** (0) Absent; (1) Present (Fig 29).
19.	**Wing vein R_2:** (0) Present, removed from split of R_{3+4} (Fig 16); (1) Present, beyond midlength of R_{3+4} (Fig 20); (2) Present, at split of R_{3+4} (Fig 31); (3) Absent; (4) Well before split of Rs.
20.	**Wing cell dm:** (0) Rectangular, length about twice the height (Fig 30); (1) Rectangular, elongate with length greater than 3x height (Fig 41); (2) Square, width subequal to height (Fig 16); (3) Absent.
21.	**Wing vein R_3:** (0) Slightly curved ventrally at the wing margin (Fig 21); (1) Straight to wing margin, or weakly to strongly produced dorsally (Fig 29); (2) Strongly curved ventrally at the wing margin (Fig 30).
22.	**Teeth of tarsal claws:** (0) Absent, or present as a single basal tooth; (1) Present with 2-4 strong teeth present.
23.	**Basal branch of wing vein R_5:** (0) Subequal to combined rm + M_{1+2} (Fig 15); (1) Directed to the wing base, longer than combined rm + M_{1+2} (Fig 26).
24.	**Wing cell r_4:** (0) Uniform height to wing margin; (1) Constricting strongly at wing margin (Fig 30).
25.	**Coloration of tarsomeres:** (0) Coloration similar to that of tibia; (1) Distinctly snowy white in coloration.
26.	**Placement of the tooth of the outer gonostylus:** (0) Placed distally on the style; (1) Placed at about midlength of the style.
27.	**Interbase:** (0) Present; (1) Absent.
28.	**Base of interbase strongly compressed into a distinct peak:** (0) Absent; (1) Present (Fig. 81, 91).
29.	**Basal enlargement of interbase:** (0) Absent; (1) Present as a prominent basal lobe (Figs 73, 95).

30. **Scalloping along the dorsal margin of the base of the interbase:** (0) Absent; (1) Present (Fig 95).
31. **Dorsal ridge of interbase:** (0) Absent; (1) Present as a raised ridge along the dorsal edge, terminating at about 1/3 – 1/2 the length of the interbase (Figs 75, 84).
32. **Subterminal expansion of interbase into a rounded lobe:** (0) Absent; (1) Present (Figs 95-96).
33. **Apex of interbase elongate, narrowing to a fine tip:** (0) Absent; (1) Present (Figs 81, 86).
34. **A medial crease, or split, present along the dorsal face of aedeagus:** (0) Absent; (1) Present (Figs 128, 143).
35. **Apex of aedeagus split at margin:** (0) Absent; (1) Present (Figs 144).
36. **Dorsal aedeagus with medial ridge appeased to aedeagus:** (0) Absent; (1) Present; (2) Dorsal face widely split medially (Figs 100, 114).
37. **Dorsal expansion of aedeagal:** (0) Absent (Figs 120, 152); (1) Present as a weakly raised to prominent lobe (Figs 112, 126, 147).
38. **Form of Dorsal aedeagus expansion:** (0) Present as a single lobe, may be tightly appeased to the aedeagus (Figs 128, 148); (1) Prominent sclerotized bifid lobes (Fig 116); (2) short strongly sclerotized lobes, split wide medially (Figs 100, 114).
39. **Ventral lobe of aedeagus:** (0) Absent; (1) Present on single branch of aedeagus (Figs 103, 121, 137).
40. **Orientation of aedeagus:** (0) Directed posteriorly (Fig 111, 133); (1) Directed ventrally, apex variably directed (Fig 101, 117, 125, 137).
41. **Sinuous bend at apex of aedeagus:** (0) Absent; (1) Present on a single branch (Fig 137, 146); (2) Present on each branch of the aedeagus (Fig 117).
42. **Aedeagus projected under the sperm sac:** (0) Absent; (1) Present (Fig 125).
43. **Terminal branches of aedeagus:** (0) Singular (Fig 103-104); (1) Bifid (Fig 102).
44. **Elongate branches of bifid aedeagus:** (0) Absent; (1) Present (Fig 102).
45. **Apex of aedeagal branches reduced, not with a well-defined margin:** (0) Absent; (1) Present (Figs 118).

Table S4. Relative support (%) of nodes recovered during the Bayesian binary MCMC (BBM) analysis conducted in RASP 3.0. Biogeographic regions: WP=Western Palearctic; EA=Eastern Asiatic; WN=Western Nearctic; EN=Eastern Nearctic; CA=Caribbean; IT=Irano-Turanian; IN=Indian; M=Malesian.

Tree node	Biogeographic region and support				
Root	WP 95.33				
Clade A	WP 99.74				
Clades B-C	WP 76.86	EA 7.31			
Clade B	IN 50.52	EA 18.58	WP 13.52		
L. neotropica-L. tokunagai	EA 55.48	CA 27.71	EA/CA 8.96		
L. kashmirica-L. nullusarma	IN 99.18				
L. n. nobilis-L. n. iranica	WP 94.42				
L. remota-L. n. nobilis	WP 98.29				
L. n. nobilis-Clade C	WP 77.67	WP/EA 11.05	EA 7.53		
Clade C	EA 64.73	WP 14.82	EA/WP 14.66		
Clade C *minus L. yamamotoana*	EA 40.56	WP 22.27	IN 15.44	EA/WP 8.95	EA/IN 6.21
Clade D	IN 92.62				
L. kraussiana-L. chettri	IN 87.44	M/IN 7.30			
L. assamica-L. chettri	IN 98.54				
L. orthotenes-L. flavissima	IN 99.37				
L. decurvata-L. flavissima	IN 99.74				
L. malla-L. flavissima	IN 99.86				
Clade E-L. errans	EA 40.97	WP 32.15	EA/WP 22.28		
Clade E	EA 94.58				
L. mirabilis-L. hynesiana	EA 98.04				
L. pluto-L. hynesiana	EA 93.62				
L. sylvia-L. taiwanica	EA 96.13				
L. sylvia-L. nigrilinea	EA 81.63	EA/EN 6.65	EN 5.37		
L. babai—L. nigrilinea	EA 83.49	EA/WN 9.49	WN 5.02		
L. shasta-L. nigrilinea	WN 97.02				
L. fenderi-L. taiwanica	EA 97.77				
L. fenderi-L. apicifusca	EA 93.22				
L. leucopeza-L. taiwanica	EA 99.70				