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Biological, behavioural and morphological tools in the biosystematics of Reduviidae (Insecta—Heteroptera—Reduviidae)

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Abstract. Biosystematic studies of 3 subfamilies of Reduviidae viz Acanthaspidinae, Harpactorinae and Piratinae have provided sufficient data for clear demarcations of these subfamilies in terms of biological, behavioural and morphological tools. Biological considerations involve incubation and stadial periods, hatchability, adult longevity, sex ratio and morphometric analyses of life stages. Behavioural parameters include nature of predators, camouflaging, death feigning, head nodding, spitting, nymphal rolling, mating and oviposition of the members of these 3 subfamilies. Information on the bioecology of 25 species, behavioural aspects of 40 species and morphological aspect of 165 species serve to adequately augment our understanding of the biosystematics of this important predatory group of insects.

Keywords. Biosystematics; Reduviidae; Acanthaspidinae; Harpactorinae; biological; behavioural Piratinae, morphological tools.

1. Introduction

Members of Reduviidae constitute one of the major groups of predatory insects and many of them are reported to be predating on a number of insect pests of agriculture and forestry and efforts have been made to employ them as agents of biological control against insect pests (Ambrose 1987). Distant (1903, 1910) in his Fauna of British India volumes described and classified 342 species of Reduviids under 106 genera and 13 subfamilies based on morphological characters. Samuel and Joseph (1953), Muraleedharan (1976) and Ambrose and Livingstone (1986a, b) described two species of *Rhinocoris*, two species of *Henricohahnia*; species of *Rhinocoris* and a new genus namely *Neohaematorrhophus* (*N. therasii*) respectively. Goel (1984) reported the taxonomic relationships of the subfamilies of Reduviidae as indicated by the thoracic skeleton. Ambrose (1980, 1987) and Livingstone and Ambrose (1978a, b, 1984) discussed the biological, behavioural and morphological peculiarities of subfamilies of Reduviidae. Haridass (1985, 1986a, b) described the ultrastructure of the eggs of 4 subfamilies of Reduviidae. No information is available on the biological, behavioural and morphological parameters in the biosystematics of Reduviidae. Informations on the bioecology of 25 species, behavioural aspects of 40 species and morphological aspects of 165 species augment our understanding of the biosystematics of this important predatory group of insects. The present paper deals with the biological, behavioural and morphological tools derived from 85 species which can be used to clearly demarcate 3 subfamilies of Reduviidae viz Acanthaspidinae, Harpactorinae and Piratinae.

2. Materials and methods

The species studied presently are given in table 1. Insects were collected from the scrub jungles, semiarid zones and tropical rain forest of Southern India. They were

Table 1. Species of Reduviids studied.

I. ACANTHASPIDINAE

1. *Acanthaspis bistillata* Stål x, 2. *A. pedestris* Stål xxx, 3. *A. siva* Dist xxx, 4. *A. livingstonei* sp. nov., 5. *A. philomanmariae* sp. nov. xxx, 6. *A. subrufa* Dist. x, 7. *A. quinquespinosa* Fabr. xxx, 8. *A. zebraica* Dist. x, 9–17. *Acanthaspis* spp. (9), 18. *Edocla slateri* Dist. xxx, 19. *E. pelia* Dist. x, 20. *Linshcosteus cornifex* Dist. x, 21. *Linshcosteus* sp., 22. *Pasira perpusilla* Walk. x, 23. *Sminthocoris fuscipennis* Stål x, 24. *Triatoma rubrofasciatus* De geer x, 25. *Velitra sinensis* Walk., 26. *Velitra* sp.

II. HARPACTORINAE

27. *Coranus atricapillus* Dist. x, 28. *C. spiniscutis* Reut. x, 29. *C. vitellinus* Dist. xxx, 30–31. *Coranus* spp. x (21), 32. *Cydnocoris gilvus* Burm. x, 33. *C. crocatus* Stål x, 34. *Endochus cingalensis* Stål x, 35. *E. inoratus* Stål x, 36. *E. migratorius* Dist. x, 37. *Euagoras plagiatus* Burm. xxx, 38. *E. typicus* Dist., 39. *Irantha armipes* Stål xx, 40. *I. consobrina* Dist. x, 41. *Lophocephala querini* Lap. xxx, 42. *Polididus armatissimus* Dist. xxx, 43. *Rhaphidosoma atkinsoni* Bergr. xx, 44. *Rhaphidosoma* sp., 45. *Rhinocoris fuscipes* Fabr. xxx, 46. *R. kumarii* Amb. and Liv. xxx, 47. *R. longifrons* Stål xxx, 48. *R. marginatus* Fabr. xxx, 49. *R. marginellus* Fabr. xxx, 50–55. *Rhinocoris* spp. (6), 56. *Sphadanolestes aterrimus* Dist. xxx, 57–58. *Sphedanolestes* spp. (2) x, 59. *Sycanus ater* Wolff x, 60. *S. reclinatus* Dohra xxx, 61. *S. pyrrhomelas* Walk. xxx, 62–63. *Sycanus* spp (2) x.

III. PIRATINAE

64. *Catamiarus brevipennis* Serv. xxx, 65. *Ectomocoris atrox* Stål x, 66. *E. cordatus* Wolff x, 67. *E. cordiger* Stål x, 68. *E. elegans* Fabr. x, 69. *E. erebus* Dist. x, 70. *E. gangeticus* Bergr. x, 71. *E. ochropterus* Stål, 72. *E. quadriguttatus* Fabr. x, 73. *E. tibialis* Dist. xxx, 74. *E. vishnu* Dist. xxx, 75. *Ectomocoris* sp. xxx, 76–78. *Ectomocoris* spp. (3) x, 79. *Pirates affinis* Serv. xx, 80. *P. quadrinotatus* Fabr. x, 81–82. *Pirates* spp. (2), 83. *Sirthenea flavipes* Stål x.

x—Morphological characters studied; xx—Behavioural and morphological characters studied; and xxx—Biological, behavioural and morphological characters studied.

References: Ambrose (1978, 1980, 1983, 1986), Ambrose and Livingstone (1978, 1979, 1984, 1985a, b, 1986a, b, c, d), Ambrose *et al* (1985), Livingstone and Ambrose (1978a, b and 1984) and Vennison and Ambrose (1986).

reared in the plastic containers (12 × 6 × 4 cm) under laboratory conditions. (temperature −32°C; RH 80–85% and photoperiod 12 to 13 h) on houseflies, grasshoppers, catterpillars and camponotine ants. Eggs laid by the insects were collected and allowed to hatch, and the nymphs hatched were reared in the plastic containers. Observations like incubation period, stadial period, hatchability, adult longevity and sex-ratio were made. Morphometric analyses of life stages were carried out under the microscope with micrometers. Behaviours like predation, nymphal camouflaging, death feigning, head nodding, spitting, nymphal rolling, mating and oviposition were studied both in the field and in the laboratory. For morphological studies, structures like egg, leg, rostrum, tibial pad and wings were treated with 10% KOH, 5% glacial acetic acid, dehydrated in alcohol, cleared in zylol, mounted in canadabalsom or DPX and observed under the microscope. Indices like oviposition days index (percentage of egg laying days in the total adult female longevity), tibial index (area of tibial pad ÷ area of tibia), lateral oviduct index (length of lateral oviduct ÷ length of ovary) and egg index (length of egg ÷ length of adult female insect) were calculated.

3. Observations

The biological, behavioural and morphological tools derived from 85 species belonging to 24 genera to demarcate subfamilies Acanthaspidinae, Harpactorinae and Piratinae are presented in tables 2–7.

3.1 *Biological tools*

Tables 2 and 3 show the biological demarcations among these 3 subfamilies as indicated by the incubation and stadial periods, time of eclosian and ecdysis, adult longevity, sex ratio, preoviposition period, fecundity rate and hatchability.

3.2 *Behavioural tools*

3.2a *Predatory behaviour*: Table 4 exhibits the predatory behavioural tools to demarcate the 3 subfamilies as indicated by their acts (figures 1–3), the duration of acts, different grades of nymphal congregational feeding and cannibalism (figure 7).

3.2b *Mating behaviour*: Mating behavioural demarcation of these subfamilies are clearly seen in the acts of mating, duration of mating acts, premating and postmating periods, ejection of spesmatophore capsule, frequency of mating and the interval between two successive matings (table 5 and figures 4–6).

3.2c *Oviposition behaviour*: Eggs are laid above or just below the soil surface in Acanthaspidinae, above the leaves or trunk of plants or on stones in Harpactorinae and below the soil surface in Piratinae. Members of Acanthaspidine and Piratinae

Table 2. Biological tools to demarcate the subfamilies of Acanthaspidinae (A) Harpactorinae (H) and Piratinae (P).

Tools	A	H	P
Incubation period (days)			
	18 ± 5·5	11·1 ± 3·1	27·3 ± 10·7
	(9–45)	(6–23)	(13–46)
Eclosion	Early morning	Afternoon	Night
Stadial period (days)			
Shortest	II (or) III	II (or) III	
	(II = III)	(II III)	II
I–Adult	91 ± 19·9	62·8 ± 20	120·8 ± 54
	(63–117)	(41–105)	(75–215)
Ecdysis	Night (or) early morning	Afternoon	Night
Adult longevity (days)			
Male : Female	90 : 110	50 : 50	43 : 62
	(50–201 : 47–204)	(13–72 : 14–80)	(28–70 : 43–96)
Sex ratio			
Male : Female	1 : 0·9	0·6 : 1·0	1·0 : 0·8
Generation	Multi voltine	Multi voltine	Univoltine

Numbers in parentheses indicate the range ($\bar{X} \pm SD$).

Table 3. Biological tools to demarcate the subfamilies Acanthaspidinae (A) Harpactorinae (H) and Piratinae (P).

Tools	A	H	P
Female adult longevity in days	113 ± 56 (52–185)	59·4 ± 37·2 (21–138)	52·5 ± 4·5 (48–57)
Preoviposition period in days	39 ± 11 (26–59)	21·1 ± 10·5 (8–42)	14 ± 1 (13–15)
Total no. of batches of eggs	31·6 ± 13·3 (14–55)	9·6 ± 5·1 (2–15)	17 ± 2 (15–19)
Total no. of eggs	121 ± 37 (62–166)	180·2 ± 72·6 (15–279)	93·5 ± 19·5 (74–113)
Average no. of eggs/batch	4 ± 1 (2–5)	23·1 ± 20 (3–68)	6 ± 2 (4–8)
Minimum no. of eggs/batch	1 ± 0	11·2 ± 17·79 (1–58)	2 ± 0
Maximum no. of eggs/batch	9 ± 1·5 (7–11)	81·9 ± 30·9 (5–97)	10 ± 1 (9–11)
No. of nymphs hatched	49 ± 22 (20–87)	61·5 ± 40 (12–144)	20 ± 6 (14–26)
Hatching (%)	48·2 ± 21 (28–85)	78·8 ± 12·11 (64–100)	25·5 ± 2·5 (23–28)
Frequency of hatching (0%)	14 ± 13 (1–28)	2·4 ± 1·4 (0–4)	9 ± 1 (8–10)
Frequency of hatching (100%)	7 ± 5 (2–15)	4·8 ± 2·3 (1–7)	1·5 ± 0·5 (1–2)

Numbers in parentheses indicate the range ($\bar{X} \pm SD$).

Table 4. Predatory behavioural tools to demarcate the subfamilies Acanthaspidinae (A). Harpactorinae (H) and Piratinae (P).

Tools	A	H	P
Acts of predation			
Arousal	Fast (1–4 s)	Slow (5·6 s)	Instantaneous
Approach	Fast (1–20 s)	Slow (or) waiting (20 s 1 h)	Aggressive (1–4 s)
Capturing	Pouncing with legs (3–30 s)	Pinning with rostrum (10 min–3·5 h)	Pouncing with legs (2–15 s)
Paralysing	Slowly (10 s–2 min)	Quickly (2–60 s)	Slowly (20 s–3 min)
Sucking	Firm predator grip released but hold the prey with legs (21 min–3 h)	Lifting the prey with the rostrum (or) holding the prey with legs (20 min–1·5 h)	Predator grip released and sucked at its ease (1 h–6 h)
No. of sucking sites	More (12–20)	Less (8–15)	More (20–30)
Nymphal congregational feeding	In early instars	In all instars	Absent
Nymphal cannibalism	In all instars	In early instars	In all instars

Values in parentheses indicate the range.

Table 5. Mating behavioural tools to demarcate the subfamilies Acanthaspidinae (A), Harpactorinae (H) and Piratinae (P).

Tools	A	H	P
Premating period in days	Short (9–15)	Long (10–20)	Shortest (6–8)
Post mating period prior to oviposition	Long (12–39)	Shortest (5–20)	Longest (31–40)
Acts of mating	Fast	Slow	Fastest
Arousal	(2 s–20 min)	(2 s–20 min)	(2–3 s)
Approach	Similar to Predatory (3–40 s)	Lethargic (10 s–10 min)	Aggressive (1–5 s)
Precopulatory cannibalism of incompatible partner	Rarely present	Absent	Present
Precopulatory riding	Absent	Present (8 s–3 h)	Absent
Duration of copulation	Short (9 min–2 h)	Long (20 min–8 h)	Very short (17–20 min)
Position of copulation	Side to side	Side to side and V end to end	End to end and V side to side
Time for ejection of spermatophore capsule	More (34 min–8 h)	Less (7 min–4 h)	More (40 min–8 h)
Post copulatory cannibalism	Present	Rarely present	Predominantly present
Frequency of mating	Highest (8–34)	Intermediate (10–20)	Lowest (6–8)
Interval between mating	Short (1 h–7 days)	Long (1–36 days)	Long (4–19 days)

Values in parentheses indicate the range.

Table 6. Morphological tools to demarcate the subfamilies Acanthaspidinae (A), Harpactorinae (H) and Piratinae (P).

Tools	A	H	P
Colour			
Adults	Warning < dull	Dull < bright	Warning
Nymphs	Brown	Ochraceous	Brownish black < black
Wing	Sexual dimorphism male-alate female-apterous (or) micropterous	Alate	Sexual dimorphism male-alate female-apterous and alary polymorphism in both sexes
Rostrum	Curved	Straight (or) slightly curved	Deeply curved
Nymphal hairs	Straight hairs and stiff tufts of hairs at the dorsum and margin of abdomen	Straight and club shaped hair all over the body	Only straight hairs
Egg	globose > oval	Elongate	Elongately oval
Tibial pad	Well developed	Absent > poorly developed	Highly developed

Table 7. Morphometric analytical tools to demarcate the subfamilies of Acanthaspidinae (A), Harpactorinae (H) and Piratinae (P).

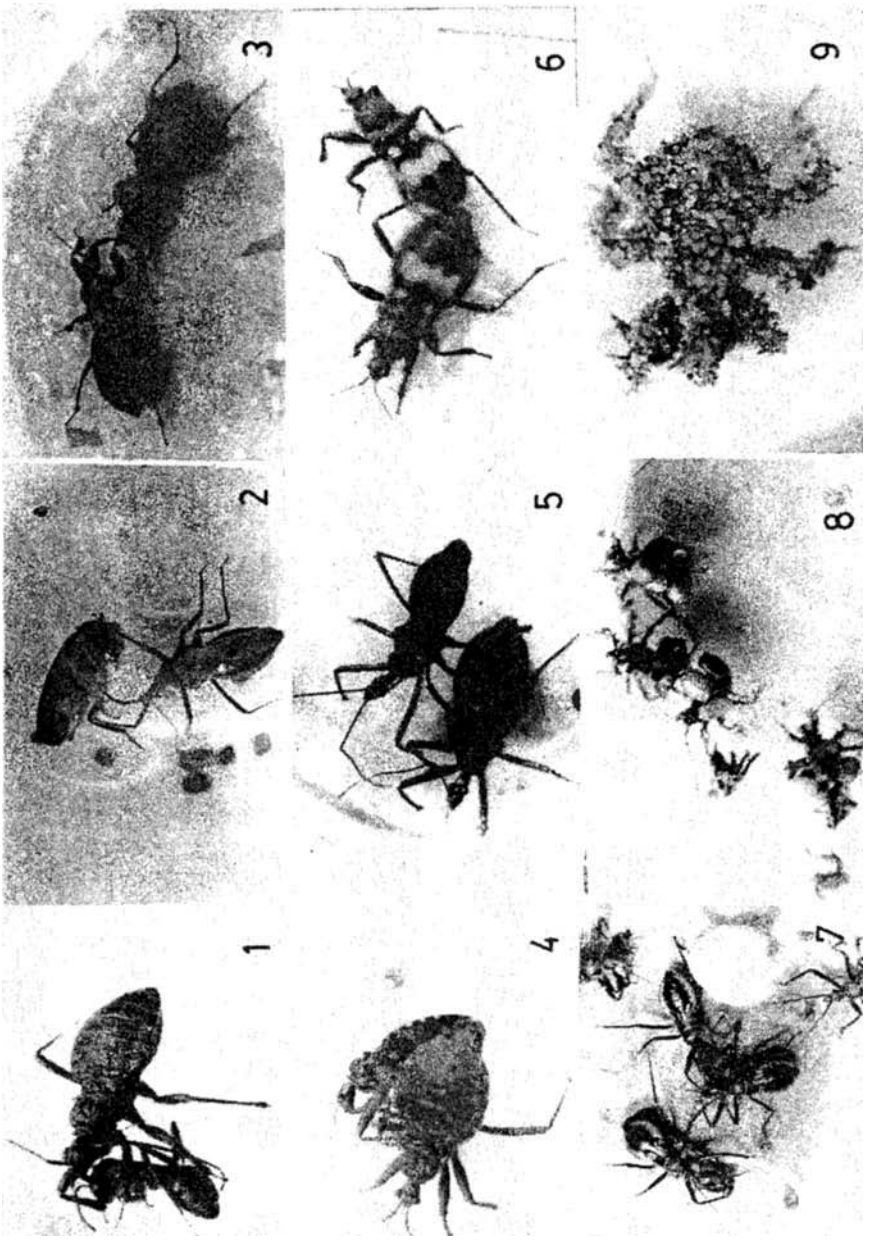
Tools	A	H	P
Anteocular postocular length	AO = PO (50%) or AO < PO (50%)	AO < PO (60%) AO = PO (40%)	AO > PO (100%)
Antennal segments			
Shortest	Scape	Pedicel	Scape
Longest	I Flagellar	Scape (40%) (or) II Flagellar	Flagellar
Rostral segments			
Shortest	Medial	Terminal (60%) Basal (40%)	Medial
Longest	Basal (50%) (or) Terminal (50%)	Medial	Basal (50%) (or) Terminal (50%)
Prothorax length : width	1 : 08	1 : 09	1 : 07
Tibia shortest	Fore (or) Mid	Mid	Mid
Fore tibial index	0·1 ± 0·04	0·05 ± 0·02	0·05 ± 0·03
$\left(\frac{\text{Area of fore tibia}}{\text{Area of insect}}\right)$	(0·03–0·15)	(0·02–0·14)	(0·01–0·12)
Fore tibial pad index	0·23 ± 0·15	0·04 ± 0·02	0·63 ± 0·26
$\left(\frac{\text{Area of fore tibial pad}}{\text{Area of fore tibia}}\right)$	(0·12–0·54)	(0·01–0·06)	(0·2–1·02)
Egg index	0·07 ± 0·01	0·12 ± 0·04	0·1 ± 0·01
$\left(\frac{\text{Length of egg}}{\text{Length of insect}}\right)$	(0·05–0·09)	(0·06–0·18)	(0·09–0·11)
Lateral oviduct index			
$\left(\frac{\text{Lateral oviduct length}}{\text{Ovary length}}\right)$	0·11 ± 0·03	0·1 ± 0·02	1·6

lay the eggs loosely but the former prefer to glue the eggs to fresh excreta. Harpactorinae reduviids lay the eggs in definite pattern and the eggs are cemented with each other and to the substratum (table 8).

3.2d *Nymphal camouflaging*: Present only in Acanthaspidinae (figures 8 and 9).

3.2e *Death feigning*: Observed only in Harpactorinae.

3.2f *Head nodding*: Obscurely developed in Harpactorinae, present in Acanthaspidinae and aggressively developed in Piratinae with 'crich-crich' sound as a defensive mechanism.



Figures 1–9. **1.** *A. pedestris* exhibit Acanthaspidine type predation. **2.** *R. marginatus* show characteristic Harpactorine prey lifting. **3.** *P. affinis* displays piratine predation at ease. **4.** *A. pedestris* at side to side position of mating. **5.** *R. kumarii* at precopulatory riding over. **6.** *C. brevipennis* at side to side copula. **7.** *R. marginatus*-nymphal congregational feeding. **8 and 9.** *A. pedestris*-nymphal camouflaging.

Table 8. Ovipositional, nymphal camouflaging, death feigning, head nodding and spitting behavioural tools to demarcate the subfamilies Acanthaspidinae (A), Harpactorinae (H) and Piratinae (P).

Tools	A	H	P
Oviposition			
Eggs laid	Joint below (or) above the surface of soil	On tree trunks, leaves and stones	Deep inside the soil
Mode of egg laying	Loosely, preference to glue the eggs to fresh excreta	In batches eggs are cemented together and to the substratum	Loosely no preference to glue the eggs to fresh excreta
Nymphal camouflaging	Present	Absent	Absent
Death feigning	Absent	Present	Absent
Head nodding	Present	Obscurely present	Aggressive with crich-crich sound
Spitting of watery saliva	Absent	Present	Absent

3.2g *Spitting of watery saliva*: Only the members of Harpactorinae spit the watery saliva at provocation.

3.3 *Morphological tools*

Morphological tools like colour of adults and nymphs, nature of wing, rostrum, nymphal hairs, eggs and tibial pad, the length of antocular and postocular areas, antennae, rostrum, tibia, prothorax and foretibial, foretibial pad, egg and lateral oviduct indices are given in tables 6 and 7.

4. Discussion

The foregoing account on the biological, behavioural and morphological parameters of 85 species clearly demarcate the subfamilies Acanthaspidinae, Harpactorinae and Piratinae. Acanthaspidinae has the following characteristic features: moderately long incubation and stadial periods, eclosion and ecdysis at night, II or III stadium the shortest, females live longer than males, sex ratio slightly male biased, long preoviposition period, more number of egg batches with comparatively lesser number of eggs, fairly good hatchability, efficient prey capturing, nymphal cannibalism and nymphal congregational feeding in early instars, short premating period, mating acts similar to the acts of predation, short duration of copulation of side to side position, long time taken to eject the spermatophose capsule, frequent mating with short intervals, dull or warning coloured adults, curved rostrum, globose or oval eggs, well developed tibial pad, brown colour nymphs with tufts of stiff median and lateral abdominal hairs, scape and the first flagellar segments as the shortest and longest antennal segments, medial rostral segment as the longest, highest tibial index, intermediate tibial pad index, lowest egg index and moderate lateral oviduct index, eggs loosely laid but glued to excreta, nymphal camouflaging and fairly developed head nodding behaviour.

Harpactorine members have shortest incubation and stadial periods, shortest

stadiun mostly in the third instar, eclosion and ecdysis occur in the afternoon, male and female with equal longevity, female biased sex ratio, moderately long preoviposition period, less number of batches of eggs with more number of eggs, highest hatchability, poor prey capturing efficiency, quickly paralysing the prey, lifting the prey with rostrum, less sucking time with less number of sucking sites, nymphal congregational feeding in all instars, nymphal cannibalism in early instars, long premating and copulation period with a characteristic precopulatory riding, short time to eject the spermatophore capsule, fairly good frequency of mating with long interval of mating, alate, brightly coloured adults, ochraceous nymphs with straight and club shaped hair, elongate eggs, poorly developed tibial pads, slightly longer postocular area, pedicel the shortest and the scape or the II flagellar the longest segments of antenna, medial rostral segment the longest, mid tibia the shortest, poor fore tibial and fore tibial pad indices, highest egg index, poor oviduct index, elongate eggs laid in clutches and cemented together and to the substratum, death feigning and spitting behaviour.

Piratine reduviids have longest incubation and stadial periods, eclosion and ecdysis at night, short adult longevity, males live longer, female biased sex ratio, short preoviposition period, poor fecundity and hatchability, efficient and aggressive prey capturing,. strongly developed nymphal cannibalism, aggressive mating behaviour with short duration of copulation, lowest frequency of mating with longest interval between mating, adults warningly coloured, brown or black nymphs, alary polymorphism, deeply curved rostrum, elongately oval eggs, highly developed tibial pad, longer anteocular area, scape the shortest and flagellar the longest antennal segments, medial rostral segment the longest, shortest tibial pad and lateral oviduct indices, eggs laid deep inside the soil, aggressive head nodding with 'crich-crich' sound.

The biological, behavioural and morphological parameters exhibited by these 3 subfamilies not only demarcate them from each other but also indicate the affinities in between them. Subfamily Acanthaspidinae is more closer to Piratinae and also intermediate in between Harpactorinae and Piratinae. This observation also lead to an understanding of their evolutionary origin. Livingstone and Ambrose (1984) traced the evolutionary origins of the subfamilies of Reduviidae and their observations very closely corroborate with the present study.

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