

## REVIEW ARTICLE

# The forgotten tigers: the arboreal tiger beetles of Sri Lanka

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**Summary:** Thirty-one species of arboreal tiger beetles are known to occur in Sri Lanka of which twenty-five species are stated to be endemic. However, the group has not been studied for more than a century and the last organised records are provided by Fowler (1912) in his studies of the 'Fauna of British India including Ceylon and Burma (Coleoptera General Introduction and Cicindelidae and Paussidae)'. Due to high endemicity rates, biodiversity value and current disturbances and destruction to natural forests of the country, which are the main habitat types of the arboreal tiger beetles, it is important that this insect group be thoroughly studied. Therefore, a study was initiated on the 'Diversity, distribution and habitat types of arboreal tiger beetles (Coleoptera, Cicindelinae) of Sri Lanka', funded by the National Science Foundation of Sri Lanka. This review compiles and records previous information on the arboreal tiger beetles of Sri Lanka, which will provide a foundation for future studies and reveal gaps in the knowledge of this insect group. The review discusses: 1) taxonomy of the arboreal tiger beetles, highlighting the genera found in Sri Lanka and their affinities to arboreal tiger beetle genera elsewhere in the world; 2) previous locations and distribution of species throughout the island and districts and provinces from which species are not recorded, habitat and micro-habitat types; 3) morphological characters of genera and species and unique characters used for the separation of species, life-cycle strategies; and 4) methods employed to collect arboreal tiger beetle species and threats to the survival of this insect group.

**Keywords:** Arboreal tiger beetles, historical records, Sri Lanka.

## INTRODUCTION

Tiger beetles are predatory beetles of the order Coleoptera, family Carabidae and sub-family Cicindelinae (Roza & Mermudes, 2017). The sub-family consists of

2,822 species of 120 genera that are included into five tribes – Amblycheilini, Manticorini, Megacephalini, Collyridini and Cicindelini (Ball *et al.*, 2011; Roza & Mermudes, 2017). Two tribes are found in Sri Lanka; Cicindelini, consisting of ground dwelling tiger beetles, and Collyridini consisting of arboreal tiger beetles. Forty species of ground dwelling tiger beetles of which fourteen species are potentially endemic and thirty-one species of arboreal tiger beetles of which twenty-five are potentially endemic were found on the island (Tennent, 1860; Horn, 1904; Fowler, 1912; Naviaux, 1984; 1986; 1995; Acciavatti & Pearson, 1989). Therefore, Sri Lanka is ranked number one amongst the top ten countries with the highest tiger beetle species coverage, and number four amongst the top ten countries with highest percentage of endemic tiger beetle species (Santos, 2011).

The ground dwelling tiger beetles of Sri Lanka have been extensively studied, and species lists (Tennent, 1860; Horn, 1904; Fowler, 1912; Naviaux, 1984; Acciavatti & Pearson, 1989), locations and distributions (Horn, 1904; Fowler, 1912; Naviaux, 1984; Acciavatti & Pearson, 1989), endemic species (Dangalle *et al.*, 2011a; 2011b), habitat types (Dangalle *et al.*, 2012a; 2014a; Dangalle, 2013), habitat specificity (Dangalle *et al.*, 2012b), phylogenetic relationships based on mitochondrial DNA (Dangalle *et al.*, 2014b), body size and habitat relationships (Dangalle *et al.*, 2013a; Edirisinghe *et al.*, 2014), co-occurrence of species (Dangalle & Pallewatta, 2015) and bioindicator potential (Dangalle, 2012; Thotagamuwa *et al.*, 2016) are well known. However, the arboreal tiger beetles of Sri Lanka have been scarcely studied and detailed information on the species is only

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given by Fowler (1912). Tennent (1860), Horn (1904) and Naviaux (2002) provide the species names that occur in Sri Lanka, while one species is discussed in detail by Naviaux (1995). Considering the high endemism rate of 80 % of arboreal tiger beetles, increased habitat degradation and forest destruction due to developmental activities of the country, it is imperative that the arboreal tiger beetles of Sri Lanka be studied and documented.

### Past records on the arboreal tiger beetle species of Sri Lanka

Arboreal tiger beetles are commonly found in the tropics and subtropics of Asian countries inhabiting plant leaves and branches in forests (Toki *et al.*, 2017). About 470 species are described in the world and are included in the tribe Collyridini, which is further divided into three subtribes – Ctenostomina, Collyridina and Tricondylina (Toki *et al.*, 2017). Subtribe Ctenostomina consists of the genera *Pogonostoma* Klug and *Ctenostoma* Klug, which are considered as ancient relics of former Gondwanaland (Cassola, 2000a). *Pogonostoma* is an endemic genus found in Madagascar and is represented by 81 species inhabiting the evergreen eastern rain forests (Andriamampianina *et al.*, 2000). Genus *Ctenostoma*, the closest relative to genus *Pogonostoma* is a neotropical genus and is found in the dark mid-strata of tropical vegetation from southern Mexico to the northern border of Argentina (Cassola, 2000a). Neither of these genera are found in Sri Lanka, and the island is only inhabited by species of the subtribes Collyridina and Tricondylina.

Collyridina of Sri Lanka consists of two genera, *Collyris* Fabricius and *Neocollyris* Horn, while Tricondylina also consists of two genera *Tricondyla* Latreille and *Derocrania* Chaudoir (Horn, 1904; Fowler, 1912; Erwin, 1984). However, Naviaux (2002) has described a fifth genus, *Protocollyris* Mandl from the country consisting of only a single species. The highest number of species are recorded from the genera *Derocrania* and *Neocollyris*; *Derocrania* consists of 12 species of which all are endemic to the island, while *Neocollyris* also consists of 12 species of which 9 species are endemic. Genus *Tricondyla* consists of 5 species of which 3 are endemic. Genus *Collyris* consists of a single species that is not endemic to the country (Table 1).

All five genera are also found in India (Saha & Halder, 1986; Saha *et al.*, 1995; Bhargav *et al.*, 2009; Cassola, 2011), while three genera - *Collyris*, *Neocollyris* and *Tricondyla* are found in Thailand (Naviaux, 1991). Species of *Collyris* and *Neocollyris* have been recorded from Vietnam (Erwin & House, 1978; Toki *et al.*, 2017), and *Neocollyris* and *Tricondyla* from the Philippine Islands (Trautner & Schawaller, 1996; Cassola, 2000b)

and Hong Kong (Aston, 2016). *Tricondyla* are also known from Brunei (Damken *et al.*, 2017).

These records are in accordance with Erwin's (1984) idea that the ground beetle fauna of Sri Lanka has its origins in the North, mainly the Oriental region. However, many of the arboreal tiger beetle species are endemic to Sri Lanka and only a few species are common with other countries – *Tricondyla femorata* Walker, *T. tumidula* Walker, *Neocollyris crassicornis* Dejean, *N. bonellii* Guérin-Méneville, *N. andrewesi* Horn and *Collyris dohrnii* Chaudoir.

Arboreal tiger beetles are known from Sri Lanka since 1860 when Emerson Tennent first recorded two species of the genus *Tricondyla*; *T. femorata*, *T. tumidula* and two species of the genus *Derocrania*; *D. scitiscabra* Walker, *D. concinna* Chaudoir. In 1904, Walther Horn provided a synopsis of 22 arboreal tiger beetles of all four genera – *Collyris*, *Neocollyris*, *Tricondyla*, *Derocrania*, but indicated his doubts of three species, *C. bonellii*, *N. andrewesi* and *T. tumidula* as belonging to the arboreal tiger beetle fauna of Sri Lanka. In 1912, Fowler in his studies of the Fauna of British India provided a more descriptive categorisation of the arboreal tiger beetles of Sri Lanka by grouping arboreal tiger beetles into the subfamily Collyrinae and dividing it into two groups. The first group is characterised by species with wings, seven teeth on labrum and females with two small sharp projections on the posterior margin of the last ventral segment of abdomen. The second group is characterised by species without wings, six labral teeth and females with no projections on the abdomen. The species of genera *Collyris* and *Neocollyris* are included in the first group, while the species of the genera *Tricondyla* and *Derocrania* are included in the second group. Fowler (1912) listed 20 arboreal tiger beetle species from Sri Lanka from all four genera. In 1995, Roger Naviaux, a French entomologist known for his work on beetles described a new endemic arboreal tiger beetle species, *Neocollyris vedda*, from Ratnapura. Later in 2002, Naviaux listed 27 species from all five genera.

Specimens of many of these species can be observed at the National Museum of Colombo and Horticultural Crop Research and Development Institute, Gannoruwa (Table 1).

### Distribution and habitat types of arboreal tiger beetles of Sri Lanka

Distributional data on arboreal tiger beetles of Sri Lanka are only provided by Horn (1904), Fowler (1912), and collections of the National Museum of Colombo and Horticultural Crop Research and Development Institute,

**Table 1:** Arboreal tiger beetle species of Sri Lanka according to previous literature

Species	Tennent, 1860	Horn, 1904	Fowler, 1912	Naviaux, 1995	Naviaux, 2002	National Museum, Colombo	HORDI, Gannoruwa
1. <i>Tricondyla femorata</i>	√	-	-	-	√	-	-
2. <i>Tricondyla tumidula</i>	√	√	-	-	-	-	-
3. * <i>Tricondyla coriacea</i>	-	√	√	-	√	√	√
4. * <i>Tricondyla nigripalpis</i>	-	√	√	-	√	√	√
5. * <i>Tricondyla granulifera</i>	-	√	√	-	√	√	√
6. * <i>Derocrania scitiscabra</i>	√	√	√	-	√	√	-
7. * <i>Derocrania concinna</i>	√	√	√	-	√	√	√
8. * <i>Derocrania nietneri</i>	-	√	√	-	√	√	√
9. * <i>Derocrania fusiformis</i>	-	√	√	-	√	√	-
10. * <i>Derocrania gibbiceps</i>	-	√	√	-	√	√	√
11. * <i>Derocrania flavicornis</i>	-	√	√	-	√	-	-
12. * <i>Derocrania nematodes</i>	-	√	√	-	√	√	√
13. * <i>Derocrania schaumii</i>	-	√	√	-	√	√	√
14. * <i>Derocrania halyi</i>	-	√	√	-	√	√	-
15. * <i>Derocrania agnes</i>	-	-	√	-	√	√	-
16. * <i>Derocrania intricatorugulosa</i>	-	-	-	-	√	-	-
17. * <i>Derocrania jaechi</i>	-	-	-	-	√	-	-
18. * <i>Protocollyris planifrons</i>	-	-	-	-	√	-	-
19. <i>Collyris dohrnii</i>	-	√	√	-	√	√	√
20. <i>Neocollyris crassicornis</i>	-	√	√	-	√	√	√
21. * <i>Neocollyris saundersii</i>	-	√	√	-	√	√	√
22. * <i>Neocollyris punctatella</i>	-	√	√	-	√	√	-
23. * <i>Neocollyris plicaticollis</i>	-	√	√	-	√	√	-
24. * <i>Neocollyris ceylonica</i>	-	√	√	-	√	√	-
25. <i>Neocollyris bonellii</i>	-	√	-	-	-	-	-
26. * <i>Neocollyris planifrons</i>	-	√	√	-	-	√	-
27. <i>Neocollyris andrewesi</i>	-	√	-	-	-	√	-
28. * <i>Neocollyris vedda</i>	-	-	-	√	√	-	-
29. * <i>Neocollyris aenea</i>	-	-	-	-	√	-	-
30. * <i>Neocollyris sedlaceki</i>	-	-	-	-	√	-	-
31. * <i>Neocollyris planifrontoides</i>	-	-	-	-	√	-	-

\* Endemic species; HORDI - Horticultural Crop Research and Development Institute

Gannoruwa. According to these data, arboreal tiger beetles are found in all nine provinces of the three climatic zones – wet, dry and intermediate. However, they have only been recorded from 16 of the 25 districts of the country and have not been recorded from Jaffna and Mannar Districts of the Northern Province; Polonnaruwa District of the North-Central Province; Batticaloa District of the Eastern Province; Kegalle District of the Sabaragamuwa Province; Gampaha, Kalutara Districts of the Western Province and Galle, Matara Districts of the Southern Province (Table 2, Figure 1).

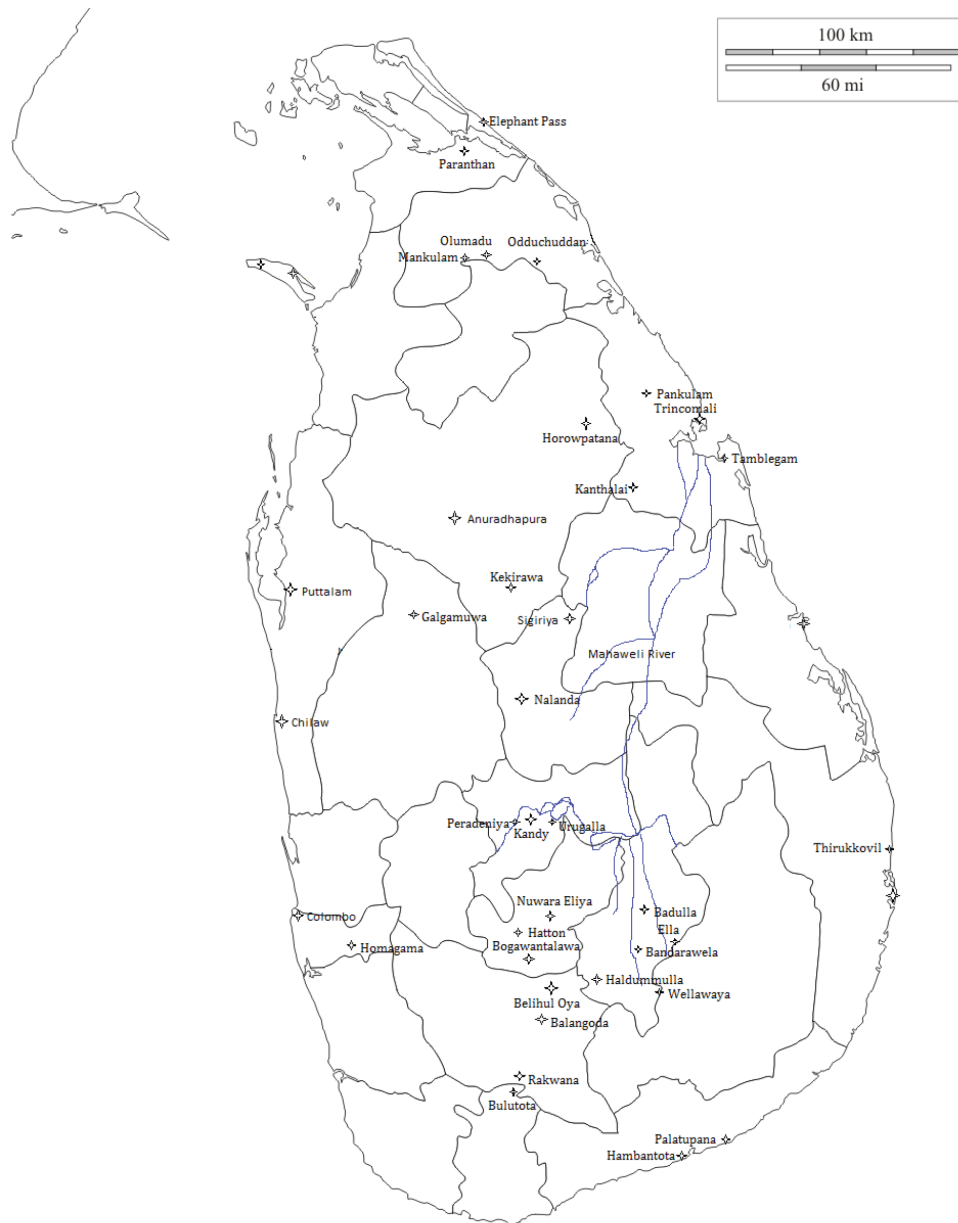
*Collyris dohrnii*, the single species of the genus *Collyris* of Sri Lanka, is recorded from locations of five provinces Northern, North-Central, Eastern, Uva and Western (Table 2) of the country but does not reveal their habitats. However, Horn (1931) in his surveys in Hong Kong recorded species of *Collyris* found on leaves and twigs of bushes, seldom settling on flowers, which may be the habitat of *C. dohrnii* of Sri Lanka.

The twelve species of *Neocollyris* of the country inhabit many locations of the Northern, Eastern, Central,

**Table 2:** Locations of the arboreal tiger beetle species of Sri Lanka

Species	Locations of occurrence
1. <i>Tricondyla femorata</i>	-
2. <i>Tricondyla tumidula</i>	-
3. <i>Tricondyla coriacea</i>	Kekirawa, Kanthalai, Palatapana, Trincomalee (Horn, 1904; Fowler, 1912); Chilaw, North-Western Province (Fowler, 1912); Kanthalai, Horowpatana, Urugalla, Mankulam, Trincomalee, Neerodumunai, Olumadu (NM, Colombo); Ella, Chilaw, Wellawaya, Kandy, Trincomalee, Thirukkivil (HORDI, Gannoruwa)
4. <i>Tricondyla nigripalpis</i>	Kongawella (Horn, 1904; HORDI, Gannoruwa); Central Ceylon (Fowler, 1912)
5. <i>Tricondyla granulifera</i>	Haragama, Nalanda (Horn, 1904; Fowler, 1912); Urugalla, Homagama (NM, Colombo); Kandy (HORDI, Gannoruwa)
6. <i>Derocrania scitiscabra</i>	Sigiriya, Nalanda (Horn, 1904); Kandy (Fowler, 1912); Urugalla, Horowpatana, Trincomalee, Badulla, Tamblegam, Galgamuwa, Uva Province, Belihul Oya, Haldummulla (NM, Colombo)
7. <i>Derocrania concinna</i>	Kandy, Nalanda, Puttalam (Horn, 1904); Kandy (Fowler, 1912); Urugalla, Rakwana, Kandy, Balangoda, Nalanda (NM, Colombo); Haragama, Kandy (HORDI, Gannoruwa)
8. <i>Derocrania nietneri</i>	Balangoda, Bogawantalawa, Nuwara Eliya, Nalanda (Horn, 1904); Balangoda Ridge, Kandy (Fowler, 1912); Urugalla, Rakwana, Bulutota, Balangoda, Bandarawela (NM, Colombo); Kandy (HORDI, Gannoruwa)
9. <i>Derocrania fusiformis</i>	-
10. <i>Derocrania gibbiceps</i>	Nalanda (Horn, 1904); Central Ceylon (Fowler, 1912); Urugalla (NM, Colombo); Kandy, Hatton (HORDI, Gannoruwa)
11. <i>Derocrania flavicornis</i>	-
12. <i>Derocrania nematodes</i>	Bogawantalawa (Horn, 1904); Central Ceylon (Fowler, 1912); Chilaw (HORDI, Gannoruwa)
13. <i>Derocrania schauimi</i>	Kekirawa (Horn, 1904); Trincomalee, Hambantota, Kandy (NM, Colombo)
14. <i>Derocrania halyi</i>	Anuradhapura, Pankulam, Kanthalai, Trincomalee, Puttalam (Horn, 1904)
15. <i>Derocrania agnes</i>	-
16. <i>Collyris dohrmii</i>	Eastern Province (Horn, 1904); Colombo (Fowler, 1912); Trincomalee, Haldummulla, Paranthan, Odduchuddan (NM, Colombo); Bandarawela (HORDI, Gannoruwa)
17. <i>Neocollyris crassicornis</i>	Elephant Pass (NM, Colombo)
18. <i>Neocollyris saundersii</i>	Bandarawela (Horn, 1904); Bandarawela, Kandy (Fowler, 1912); Kanthalai (NM, Colombo); Kandy, Wellawaya, Peradeniya, Trincomalee (HORDI, Gannoruwa)
19. <i>Neocollyris punctatella</i>	Balangoda (Horn, 1904; Fowler, 1912)
20. <i>Neocollyris plicatocollis</i>	Urugalla (NM, Colombo)
21. <i>Neocollyris ceylonica</i>	Bogawantalawa (Horn, 1904)
22. <i>Neocollyris bonelli</i>	-
23. <i>Neocollyris planifrons</i>	Wellawaya (NM, Colombo)
24. <i>Neocollyris andrewisi</i>	-
25. <i>Neocollyris vedda</i>	Ratnapura (Naviaux, 1995)

HORDI - Horticultural Crop Research and Development Institute; NM - National Museum



**Figure 1:** Locations of occurrence of the arboreal tiger beetles of Sri Lanka (according to previous literature)

Uva and Sabaragamuwa Provinces (Table 2), but habitats are only recorded for *N. crassicornis*. According to Fowler (1912), this species has been reported from jungles with less dense vegetation. They have been found running on leaves of shrubs, and flying rapidly from shrub to shrub. However, different species of *Neocollyris* have been recorded from green vegetation of forests (Saha & Halder, 1986), mixed dipterocarp forests, secondary forest edges, understory vegetation (Damken *et al.*, 2017) and wildlife sanctuaries (Bhargav *et al.*, 2009) of India; branches of coffee plants in Vietnam (Toki *et al.*, 2017);

and grasses and leaves of small *Ficus hispida* Linnaeus trees of Hong Kong (Aston, 2016).

Genus *Derocrania* consisting of twelve species is found in eight provinces of Sri Lanka, excluding the Northern Province. Fowler (1912) described the habitat of *D. scitiscabra* as tree trunks of forests.

The five species of genus *Tricondyla* of Sri Lanka display a wide distribution and are recorded from eight Provinces of the island with the exception of the Southern

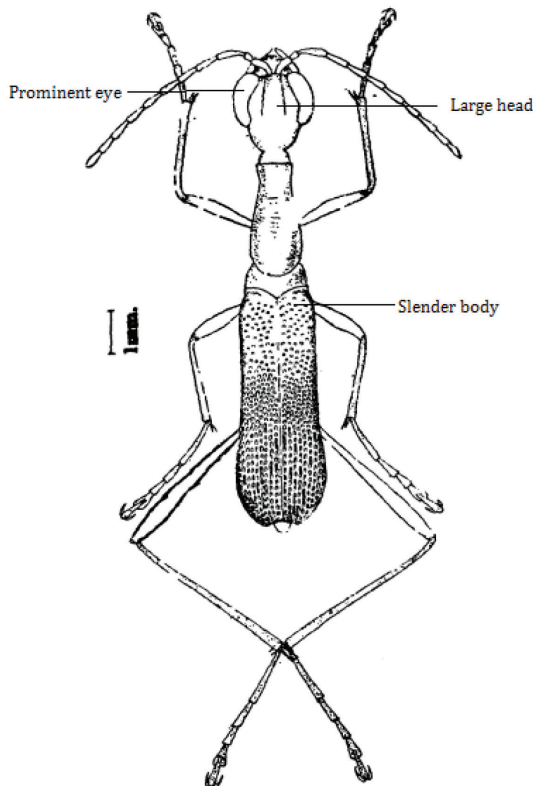
Province. Although the habitats have not been recorded for the species of Sri Lanka, according to Horn (1931), they occur on tree trunks up to a height of several feet. In Hong Kong *T. pulchripes* White has been recorded on tree trunks (Horn, 1931; Aston, 2016) and is known to frequent Lichi trees (Aston, 2016). *Tricondyla aptera* Olivier have been collected from the leaves and ground cover in jungle forests of Manila, the Philippine Islands (Tanner, 1951).

### Morphology of arboreal tiger beetles

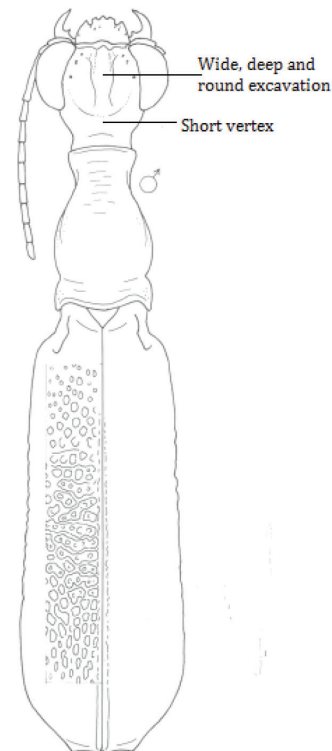
Arboreal tiger beetles have an elongate, slender body with a large head and prominent eyes (Figure 2) (Fowler, 1912). They differ from ground-dwelling tiger beetles by having an elongate slender body and very narrow, strongly furrowed episterna of the metasternum (Fowler, 1912; Saha *et al.*, 1995). The tribe consists of five genera of which *Collyris* and *Neocollyris* have wings that are capable of flight, labrum with seven teeth and two small projections on the posterior edge of the last abdominal segment of female. *Tricondyla* and *Derocrania* have

fused or rudimentary wings incapable of flight, six labral teeth and females lacking projections on the last abdominal segment (Fowler, 1912; Saha *et al.*, 1995).

Species of the genus *Collyris* are larger (~ 27 mm) than species of the genus *Neocollyris* (9 – 21 mm) and have a head that is widely, deeply and roundly excavated between the eyes. Vertex behind the eyes is very short (Figure 3) (Fowler, 1912; Saha *et al.*, 1995; Wu & Shook, 2007). Four species are known to occur in India, Thailand and Nepal – *Collyris longicollis* Fabricius, *Collyris dohrnii*, *Collyris brevipennis* Horn and *Collyris mniszewski* Chaudoir. All the species are bright blue, purple or black and *C. longicollis*, *C. dohrnii* and *C. brevipennis* have elytra that are not plicate at the center. The species *C. longicollis* has a pronotum that is strongly constricted at the base, while *C. dohrnii* and *C. brevipennis* lack this constriction. However, *C. dohrnii* has long elytra that are less regularly punctured while *C. brevipennis* has short elytra that are more regularly punctured. *Collyris mniszewski* has elytra that are plicate at the center (Fowler, 1912). Only *C. dohrnii* is found in Sri Lanka.



**Figure 2:** Dorsal view of the arboreal tiger beetle *Neocollyris shyamrupi* (adapted from Saha & Halder, 1986)



**Figure 3:** Habitus of *Collyris mniszewski* (adapted from Naviaux, 1991)

Genus *Neocollyris* consists of species that are smaller in size and have a narrow space between the eyes that is strongly impressed. Vertex behind the eyes is long and most species are blue, green or violaceous in colour (Figure 4) (Fowler, 1912; Saha *et al.*, 1995). The genus contains about 100 species of which twelve are found in Sri Lanka. *Neocollyris planifrons* Horn, *N. punctatella* Chaudoir, *N. ceylonica* Chaudoir and *N. schaumii* Horn are species that are small in size with less prominent eyes. *Neocollyris planifrons* differs from the other three species by possessing a long labrum, whereas the labrum is short in the others (Fowler, 1912). *Neocollyris bonellii* that occurs in India and other Asian countries in addition to Sri Lanka is intermediate in size with more prominent eyes. The species is metallic blue or green with a strongly dilated pronotum with a basal constriction. *Neocollyris crassicornis* Dejean, *N. saundersii* Chaudoir, *N. andrewesi* Horn and *N. plicaticollis* Chaudoir are species that are larger in size. *Neocollyris crassicornis* and *N. saundersii* have broad short heads, green, blue, violaceous, blackish colours and antennae that are strongly thickened towards the apex. In *N. crassicornis*

the pronotum is short and strongly dilated before base, while *N. saundersii* has a longer pronotum not strongly dilated before base (Fowler, 1912). Both *N. andrewesi* and *N. plicaticollis* have antennae that are not thickened towards the apex. The two species can be distinguished from each other by the frontal excavation on the head, which is broader in *N. andrewesi* when compared with *N. plicaticollis* (Fowler, 1912).

Species of the genus *Tricondyla* have large heads that are strongly concave between the eyes (Fowler, 1912; Wu & Shook, 2007). The eyes are large and very prominent and antennae are long and filiform. Labrum is large with six teeth; the central four broad and blunt and the lateral two sharper. Mentum is very short at base with central tooth absent or rudimentary, while the pronotum is more or less parallel sided and broad with constrictions in front and behind (Fowler, 1912; Saha *et al.*, 1995). Elytra are fused at the suture, base narrow and apical one-third expanded in both lateral and dorsal view (Wu & Shook, 2007). The legs are very long (Figure 5) (Fowler, 1912; Saha *et al.*, 1995).

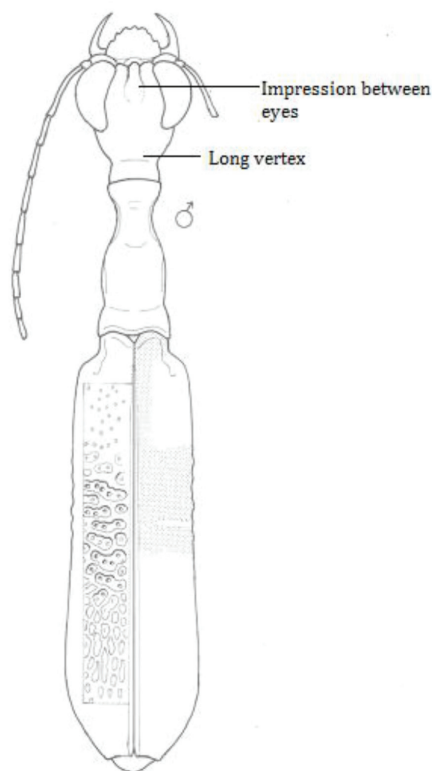


Figure 4: Habitus of *Neocollyris tricolor* (adapted from Naviaux, 1991)

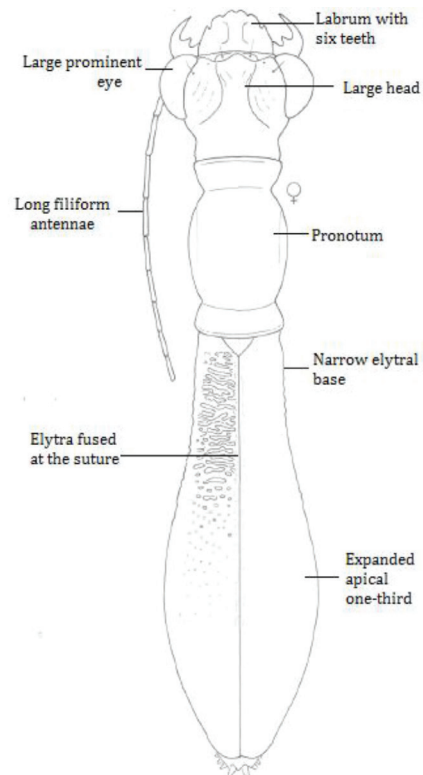
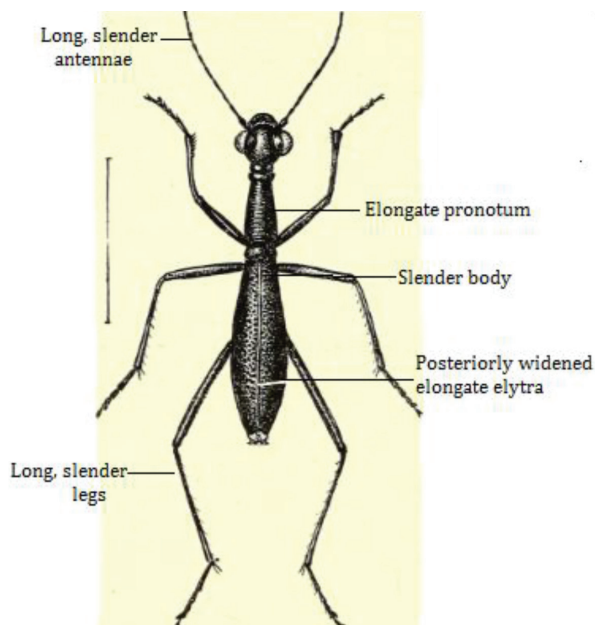


Figure 5: Habitus of *Tricondyla annulicornis* Schmidt-Goebel (adapted from Naviaux, 1991)

Nine species have been recorded from India and Sri Lanka (Fowler, 1912; Saha *et al.*, 1995) of which three have been recorded from Sri Lanka – *Tricondyla coriacea* Chevrolat, *T. nigripalpis* Horn and *T. granulifera* Motschulsky (Fowler, 1912). According to Tennent (1860) and Horn (1904), two other species – *T. femorata* and *T. tumidula* that are not known in the works of Fowler (1912) and Saha *et al.* (1995) are also known to have occurred in the country.

When considering *T. coriacea*, *T. nigripalpis* and *T. granulifera* the pronota are parallel-sided as far as the apical constriction. In *T. granulifera* the upper surface of pronotum bears a transverse sculpture, while in *T. coriacea* and *T. nigripalpis* this is not seen. *Tricondyla coriacea* has a labrum and legs that are black in colour while in *T. nigripalpis* the labrum and part of the legs are red (Fowler, 1912).

Insects belonging to the genus *Derocrania* closely resemble the species of *Tricondyla* but differ by having smaller and more slender bodies; head less excavate between the eyes; strongly strangulate vertex; slender elongate pronotum; elongate elytra that are widened behind; long and slender antennae and legs; and apex of the last abdominal sternite being pointed in the female (Figure 6) (Fowler, 1912).



**Figure 6:** Habitus of *Derocrania concinna* (adapted from Fowler, 1912)

The ten species of *Derocrania* found in Sri Lanka have punctured elytra that are transversely rugose. However, *Derocrania nietneri* Motschulsky, *D. agnes* Horn, *D. fusiformis* Horn, *D. gibbiceps* Chaudoir and *D. flavicornis* Horn have foreheads that are not excavate and pronotum forming a distinct collum. *Derocrania nietneri* and *D. agnes* are slender and delicate than *D. fusiformis*, *D. gibbiceps* and *D. flavicornis*, and punctuation of elytra are very fine and evanescent/fading behind (Fowler, 1912). The two species can be distinguished by the collum of the pronotum, which is shorter in *D. nietneri* than in *D. agnes*. *Derocrania fusiformis*, *D. gibbiceps* and *D. flavicornis* have elytra with deep and dense punctuation. *Derocrania concinna* Chaudoir and *D. schaumii* Horn have a forehead that is shallowly and widely excavate, and pronotum without a distinct collum. Elytra are more parallel and less gibbose/curved and bulging outward behind with distantly spaced elytral punctuation in *D. concinna*, while the elytra are more widened and more gibbose behind with close elytral punctuation in *D. schaumii*. *Derocrania nematodes* Schaum has an evidently excavate forehead, pronotum without a distinct collum and elytra with transversely rugose sculpture. *Derocrania scitiscabra* Walker and *D. halyi* Horn have deeply excavate foreheads and pronota with distinct collums. However, *D. scitiscabra* is smaller in size than *D. halyi* and has strongly punctured elytra (Fowler, 1912).

### Life cycle of arboreal tiger beetles

Like most Holometabola, arboreal tiger beetles pass through several stages in their life cycle before reaching adulthood (Roza & Mermudes, 2017). Oviposition is initialised by the female who uses the sclerotised gonopophyses and ovipositor to excavate a hole in the substrate into which eggs are laid (Pearson, 1988). The larva that ecloses from the egg develops for 1 – 2 years and sometimes for several years depending on the species and conditions of the environment (Roza & Mermudes, 2017). The larvae of arboreal tiger beetles burrow vertical tunnels into bulges of tender, corky bark of trees and form tunnels with a length of about 5 – 7 cm with tunnel mouths directed upwards. These larvae wait at the tunnel opening and catch prey only at night due to the availability of prey. High numbers of ants, houseflies and other arthropods are available at night running along the trunks of trees (Trautner & Schawaller, 1996). The larvae of arboreal tiger beetles are known to be different from the larvae of terrestrial tiger beetles in having shorter mandibles and pronotal setation; rounded pronotal anterior corners; deeply furrowed pronotal structure; short and broad femur and tibia; short tarsus



with short spines and short and joined claws (Trautner & Schwaller, 1996). The long larval stage of arboreal tiger beetles is followed by a short pupal stage, which is the last immature stage of the life cycle. Pupae are cylindrical in shape with sub-dorsal spines on abdominal segments 1 – 5 reduced to low tubercles with short apical setae. The prothorax shows a pair of tubercles that the terrestrial tiger beetles lack. This condition in arboreal tiger beetle pupae is considered as a specialisation related to the habitat (wood) where the pupal gallery is constructed (Roza & Mermudes, 2017).

### Methods for collecting arboreal tiger beetles

#### *Sweep nets*

Sweep nets are used to collect arboreal tiger beetles in grass and brush when vegetation is not humid or thorny (Grootaert *et al.*, 2010). Species of *Tricondyla* and *Neocollyris* have been collected from forest paths and understory vegetation in Brunei using sweep nets (Damken *et al.*, 2017).

#### *Pitfall traps*

Pitfall traps have been mostly used to collect ground-dwelling tiger beetles (Brust *et al.*, 2005; Taboada *et al.*, 2012) and is not considered as an efficient method to collect non-terrestrial tiger beetles (Franzen, 2004). However, species of *Tricondyla* have been collected using pitfall traps in Hong Kong (Aston, 2016), and *N. labiomaculata* Horn occurring in lowland mixed dipterocarp forests of Brunei have been collected using dung-baited pitfall traps (Damken *et al.*, 2017).

#### *Hand picking/ collection*

Hand picking has been used to collect arboreal tiger beetles as they are medium to large in size and do not pose a threat to health. However, the method is more effective for collecting non-flying arboreal tiger beetles. Species of *Tricondyla* have been collected from paths, edges and floors of dipterocarp forests of Brunei (Damken *et al.*, 2017).

#### *Light traps*

Although light traps have been used more effectively to collect nocturnal tiger beetles such as *Odontocheila* Castelnau, *Pentacomia* Bates and *Brasiella* Rivalier (Wiesner & Bandinelli, 2014), *T. punctipennis* Chevrolat and *T. cyanipes* Eschscholtz of the Philippines have also been collected using light traps (Cassola, 2000b).

Light traps have also been successfully used to collect arboreal tiger beetles with flight such as *Neocollyris* (*Heterocollyris*) *similior* Horn in the Philippines (Figure 7) (Cassola, 2000b).



**Figure 7:** A canopy light trap (source: <https://whitinglab.byu.edu/CanopyCollecting>)

#### *Sticky traps*

This method has been effective for collecting tree trunk dwelling arboreal tiger beetle species of genera *Pogonostoma*, *Tricondyla* and *Distipsidera* Westwood (Pearson & Vogler, 2001).

### Threats to the survival of arboreal tiger beetles

The landmass of Sri Lanka has been cleared of forest, terraced and water systems channeled and impounded. Due to these activities the carabid fauna of the island is predominantly hydrophilous – occupying waterside dwelling, highly vagile and generalist species (Erwin, 1984). However, certain carabid species such as the arboreal tiger beetles are arboricolous (Erwin, 1984) and are highly habitat specific, associated with vegetative cover, composition of flora, understory growth, herbs and grasses (Bhargav *et al.*, 2009). These habitat specific

species are affected more by changes in the habitat than ubiquitous species and eurytopic species, and are known to decline with habitat destruction and pollution (pesticides and fertilisers resulting from agricultural practices, pollutants generated from road construction, mining and siltation) (Wilcove *et al.*, 1998). In the Philippines, several tiger beetle species of *Tricondyla* and *Neocollyris* associated with forest ecosystems are considered to have disappeared due to deforestation, illegal logging and mining (Cabras *et al.*, 2016), while species of the genus *Neocollyris* inhabiting branches and trunks of shrubs and trees in lowland mixed agricultural ecosystems have become vulnerable to extinction due to various anthropogenic pressures (Cabras & Wiesner, 2016). In Hong Kong increased urbanisation and expansion of villages causing a significant loss of agricultural land, which has almost completely ceased rice cultivation, is known to have caused the demise of tiger beetles associated with this plant (Aston, 2016).

In Sri Lanka, a rapid decline in the land area under natural forest cover is evident and the wet lowland rainforests are experiencing extreme fragmentation (Dela, 2009). The wet lowland rainforests harbour nearly all the country's woody endemic flora, about 75 % of the endemic fauna and all the endemic genera (Dela, 2009). Of the thirty-six tribes of Carabidae represented in the country, the arboreal forms are associated with these forests (Erwin, 1984), and apterous forms such as the arboreal tiger beetles of genera *Tricondyla* and *Derocrania* are limited to a few lowland and highland habitats of these forests.

In addition to forest degradation, introduced and invasive species impact arboreal carabid communities. The introduced guava to forests in Madagascar has threatened indigenous vegetation, and in guava dominated sites, carabid beetle communities were species poorer than elsewhere in the forest (Rainio, 2009). A recent study conducted in Sri Lanka has revealed that changes in beetle assemblages occur when habitats were invaded by the invasive plant species, *Annona glabra* Linnaeus (Liyanagamage *et al.*, 2017). Conversion of habitats from complex to simplified forms (primary forests with higher number of plant species, high plant density and more canopy cover converted to secondary forests with a lower number of plant species, less plant density and canopy cover) is also known to affect arboreal fauna and a study in Papua New Guinea revealed that primary forests contained more arboreal ant species than secondary forests due to more complex vegetation structure and tree abundance (Klimes *et al.*, 2012). Certain arboreal lizards such as the Tree Agama depend on trees for refuge and use them as foraging

vantage points and are thus negatively affected by their removal (Whiting *et al.*, 2009). Forest habitats are also considered as important in providing arboreal escape paths for arboreal fauna avoiding predators (Mattingly & Jayne, 2005). The arboreal tiger beetles of the country with 80 % endemism are very likely to occupy the wet lowland rainforests of the island. Thus, forest destruction, pollution, habitat conversion and introduced and invasive species may have serious negative implications for their survival. However, arboreal tiger beetles are known to affect the growth of various plants in undergrowth forests in tropical and subtropical Asia due to destruction of plant soft tissue for oviposition and larval tunneling (Toki *et al.*, 2017).

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## CONCLUSION

According to previous literature thirty-one species of arboreal tiger beetles of which twenty-five are endemic are known to occur in Sri Lanka. Five genera – *Collyris*, *Neocollyris*, *Protocollyris*, *Tricondyla* and *Derocrania*, are found on the island which are also known from India, and some genera from other countries of Asia. The species of Sri Lanka occur in all zones and provinces of the country and in sixteen districts. They are known to prefer forest habitats with less dense vegetation and occupy leaves, shrubs and trunks of trees. Arboreal tiger beetles are holometabolous insects having a long sedentary larval stage and short active adult stage both of which are predatory. Species can be collected *via* sweep nets, pitfall traps, light traps, sticky traps and hand collection. The survival of arboreal tiger beetles are severely threatened by forest destruction, pollution, habitat conversion and introduced and invasive species.

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## REFERENCES

- Acciavatti R.E. & Pearson D.L. (1989). The tiger beetle genus *Cicindela* (Coleoptera, Insecta) from the Indian subcontinent. *Annals of Carnegie Museum* **58**(4): 77 – 355.
- Andriamampianina L., Kremen C., Vane-Wright D., Lees D. & Razafimahatratra V. (2000). Taxic richness patterns and conservation evaluation of Madagascan tiger beetles (Coleoptera: Cicindelidae). *Journal of Insect Conservation* **4**: 109 – 128.

- DOI: <https://doi.org/10.1023/A:1009667712512>
- Aston P. (2016). Catalogue and bibliography of the Hong Kong Carabidae Latreille, 1802 (Coleoptera: Adephaga), with notes on the historic boundaries of Hong Kong as related to zoological collections. *Zootaxa* **4121**(3): 201 – 257.  
DOI: <https://doi.org/10.11646/zootaxa.4121.3.1>
- Ball G.E., Acorn J.H. & Shpeley D. (2011). Mandibles and labrum-epipharynx of tiger beetles: basic structure and evolution (Coleoptera, Carabidae, Cicindelidae). *ZooKeys* **147**: 39 – 83.  
DOI: <https://doi.org/10.3897/zookeys.147.2052>
- Bhargav V., Uniyal V.P. & Sivakumar K. (2009). Distinctive patterns in habitat association and distribution of tiger beetles in the Shivalik landscape of North Western India. *Journal of Insect Conservation* **13**: 459 – 473.  
DOI: <https://doi.org/10.1007/s10841-008-9193-y>
- Brust M.L., Hoback W.W. & Knisley C.B. (2005). Biology, habitat preference, and larval description of *Cicindela cursitans* Leconte (Coleoptera: Carabidae: Cicindelinae). *The Coleopterists Bulletin* **59**(3): 379 – 390.  
DOI: <https://doi.org/10.1649/798.1>
- Cabras A.A., Medina M.N.D. & Wiesner J. (2016). Tiger beetles (Coleoptera: Carabidae: Cicindelinae) of Compostella Valley province, Mindanao Island, Philippines. *Biotropia* **23**(2): 137 – 143.  
DOI: <https://doi.org/10.11598/btb.2016.23.2.564>
- Cabras A.A. & Wiesner J. (2016). Tiger beetles (Coleoptera: Carabidae: Cicindelinae) of Mainit Hotspring and Mati protected landscape, Mindanao with notes on their ecology and threats. *International Research Journal of Biological Sciences* **5**(9): 16 – 21.
- Cassola F. (2000a). Studies on tiger beetles. CXII. A new *Ctenostoma* from Ecuador (Coleoptera: Cicindelidae). *Atti della Società Toscana de Scienze Naturali Memorie* **B**(107): 61 – 62.
- Cassola F. (2000b). Studies on tiger beetles. CII. The Cicindelidae collected by Roland A. Müller in the Philippine Islands, with description of three new species (Coleoptera: Cicindelidae). *Zoologische Mededelingen* **73**: 491 – 509.
- Cassola F. (2011). Studies of tiger beetles. CCII. Indian tiger beetle conservation (Coleoptera: Cicindelidae). *ENVIS Bulletin: Wildlife and Protected Areas* **14**(1): 98 – 107.
- Damken C., Wiesner J. & Wahab R.A. (2017). Notes on the tiger beetles (Coleoptera: Carabidae: Cicindelinae) of Brunei Darussalam. 137. Contribution towards the knowledge of Cicindelinae. *Insecta Mundi* **0552**: 1 – 15.
- Dangalle C.D. (2012). Tiger beetles as appropriate bioindicators of environmental change and pollution. In: Environmental toxicants and their effects on species and ecosystems (eds. C.D. Dangalle, M.R. Wijesinghe & I.C. Perera), *32<sup>nd</sup> Annual Sessions of the Institute of Biology, Sri Lanka*, pp. 55 – 63.
- Dangalle C.D. (2013). The current status of the tiger beetle species of the coastal habitats of Sri Lanka. *Journal of Tropical Forestry and Environment* **3**(2): 39 – 52.
- Dangalle C.D. & Pallewatta N. (2015). An invertebrate perspective to Hutchinson's ratio using co-occurring tiger beetle (Coleoptera: Cicindelidae) assemblages. *Taprobanica* **7**(4): 224 – 234.
- Dangalle C., Pallewatta N. & Vogler A. (2011a). The current occurrence, habitat and historical change in the distribution range of an endemic tiger beetle species *Cicindela (Ifasina) willeyi* Horn (Coleoptera: Cicindelidae) of Sri Lanka. *Journal of Threatened Taxa* **3**(2): 1493 – 1505.  
DOI: <https://doi.org/10.11609/JoTT.o2501.1493-505>
- Dangalle C., Pallewatta N. & Vogler A. (2011b). The occurrence of the endemic tiger beetle *Cicindela (Ifasina) waterhousei* in Bopath Ella, Ratnapura. *Journal of the National Science Foundation of Sri Lanka* **39**(2): 173 – 178.  
DOI: <https://doi.org/10.4038/jnsfsr.v39i2.3177>
- Dangalle C., Pallewatta N. & Vogler A. (2012a). Tiger beetles (Coleoptera: Cicindelidae) of ancient reservoir ecosystems of Sri Lanka. *Journal of Threatened Taxa* **4**(4): 2490 – 2498.  
DOI: <https://doi.org/10.11609/JoTT.o2896.2490-8>
- Dangalle C.D., Pallewatta N. & Vogler A.P. (2012b). Habitat specificity of tiger beetle species (Coleoptera, Cicindelidae) of Sri Lanka. *Cicindela* **44**(1): 1 – 32.
- Dangalle C.D., Pallewatta N. & Vogler A.P. (2013a). The association between body-size and habitat-type in tiger beetles (Coleoptera, Cicindelidae) of Sri Lanka. *Ceylon Journal of Science (Biological Sciences)* **42**(1): 41 – 53.  
DOI: <https://doi.org/10.4038/cjsbs.v42i1.5898>
- Dangalle C.D., Pallewatta N. & Vogler A.P. (2014a). Distribution and habitat preferences of tiger beetles (Coleoptera: Cicindelidae) of the riverine ecosystems of Sri Lanka. *Journal of Threatened Taxa* **6**(9): 6195 – 6203.  
DOI: <https://doi.org/10.11609/JoTT.o3674.6195-203>
- Dangalle C.D., Pallewatta N. & Vogler A.P. (2014b). Inferring population history of tiger beetle species of Sri Lanka using mitochondrial DNA sequences. *Ceylon Journal of Science (Biological Sciences)* **43**(2): 47 – 63.  
DOI: <http://dx.doi.org/10.4038/cjsbs.v43i2.7324>
- Dela J. (2009). *Fourth Country Report from Sri Lanka to the United Nations Convention on Biological Diversity*. Biodiversity Secretariat, Ministry of Environment and Natural Resources, Battaramulla.
- Edirisinghe H.M., Dangalle C.D. & Pulasinghe K. (2014). Predicting the relationship between body size and habitat type of tiger beetles (Coleoptera, Cicindelidae) using artificial neural networks. *Journal on New Biological Reports* **3**(2): 97 – 110.
- Erwin T.L. (1984). Composition and origin of the ground beetle fauna (Coleoptera, Carabidae). *Ecology and Biogeography in Sri Lanka* (eds. C.H. Fernando). Dr. W. Junk Publishers, The Hague, The Netherlands.  
DOI: [https://doi.org/10.1007/978-94-009-6545-4\\_18](https://doi.org/10.1007/978-94-009-6545-4_18)
- Erwin T.L. & House G.N. (1978). A catalogue of the primary types of Carabidae (incl. Cicindelinae) in the collections of the United States National Museum of Natural History (USNM) (Coleoptera). *The Coleopterists Bulletin* **32**(3): 231 – 255.
- Fowler W.W. (1912). *Fauna of British India including Ceylon and Burma (Coleoptera General Introduction and Cicindelidae and Paussidae)*. Today and Tomorrow's

- Printers and Publishers, New Delhi, India.
- Franzen M. (2004). Tiger beetle assemblages in a climatically transitional area of northwestern Costa Rica. *Mitteilungen der Munchner Entomologischen Gesellschaft* **94**: 87 – 95.
- Grootaert P., Pollet M., Dekoninck W. & van Achterberg C. (2010). Sampling insects: general techniques, strategies and remarks. *Manual on Field Recording Techniques and Protocols for All Taxa Biodiversity Inventories and Monitoring*. Abc Taxa, Belgium.
- Horn W. (1904). The Cicindelidae of Ceylon. *Spolia Zeylanica* **2**(5): 30 – 45.
- Horn W. (1931). How to collect cicindelids and their larvae in Hong Kong and vicinity. *The Hong Kong Naturalist* **2**(4): 258 – 261.
- Klimes P., Idigel C., Rimandai M., Fayle T.M., Janda M., Weiblen G.D. & Novotny V. (2012). Why are there more arboreal ant species in primary than in secondary tropical forests? *Journal of Animal Ecology* **81**: 1103 – 1112.  
DOI: <https://doi.org/10.1111/j.1365-2656.2012.02002.x>
- Liyanagamage M., Pallewatta N., Dangalle C. & Wijesundara S. (2017). Insect assemblages of *Annona glabra* L.; an invasive plant species in selected habitats of the wet zone. In: Conserving biodiversity through understanding relationships. *Proceedings of the 37<sup>th</sup> Annual Sessions of the Institute of Biology, Sri Lanka*, 29 September, pp. 48.
- Mattingly W.B. & Jayne B.C. (2005). The choice of arboreal escape paths and its consequences for the locomotor behavior of four species of *Anolis* lizards. *Animal Behaviour* **70**: 1239 – 1250.  
DOI: <https://doi.org/10.1016/j.anbehav.2005.02.013>
- Naviaux R. (1984). Coleoptera, Cicindelidae. Les Cicindelés de Sri Lanka. *Revue Scientifique Du Bourbonnais* **57** – 80.
- Naviaux R. (1986). Coleoptera, Cicindelidae. Premier complément aux Cicindèles de Sri Lanka. *Revue Scientifique Du Bourbonnais* **58** – 69.
- Naviaux R. (1995). *Neocollyris vedda* nouvelle espece du Sri Lanka (Coleoptera, Cicindelidae). *Bulletin de la Societe Entomologique de France* **100**(2): 173 – 174.
- Naviaux R.L. (1991). Les Cicindèles de Thaïlande, étude faunistique (Coleoptera Cicindelidae). *Bulletin Mensuel de la Société Linnéenne de Lyon* **60**(7): 209 – 288.  
DOI: <https://doi.org/10.3406/linly.1991.10944>
- Naviaux R. (2002). Les Tricondylina (Coleoptera, Cicindelidae), Révision des genres *Tricondyla* Latreille et *Derocrania* Chaudoir et descriptions de nouveaux taxons. *Mémoires de la Société Entomologique de France* **5**: 1 – 106.
- Pearson D.L. (1988). Biology of tiger beetles. *Annual Review of Entomology* **33**: 123 – 147.  
DOI: <https://doi.org/10.1146/annurev.en.33.010188.001011>
- Pearson D.L. & Vogler A.P. (2001). *Tiger Beetles: The Diversity, Ecology and Evolution of the Cicindelidae*. Cornell University Press, Ithaca, New York.
- Rainio J. (2009). Carabid beetles (Coleoptera, Carabidae) as indicators of environmental change in Ranomafana National Park, Madagascar. *Academic dissertation*, Department of Biological and Environmental Sciences, Faculty of Biosciences, University of Helsinki, Finland.
- Roza A.S. & Mermudes J.R.M. (2017). Tiger beetles' (Coleoptera: Carabidae, Cicindelinae) pupal stage: current state of knowledge and future perspectives. *Zootaxa* **4226**(3): 348 – 358.  
DOI: <https://doi.org/10.11646/zootaxa.4226.3.2>
- Saha S.K. & Halder S.K. (1986). Tiger beetles (Coleoptera, Cicindelidae) of Silent Valley (Kerala, India). *Records of the Zoological Survey of India* **84**(1 – 4): 137 – 142.
- Saha S.K., Halder S.K. & Biswas S. (1995). Insecta: Coleoptera: Adephaga: Fam. Rhysodidae, Paussidae and Cicindelidae. *Zoological Survey of India, Fauna of West Bengal* **3**(6A): 1 – 51.
- Santos B.S. (2011). Distribution patterns of tiger beetle species in the Philippines and Southeast Asia. *Journal of Entomology and Zoology Studies* **2**(4): 271 – 275.
- Taboada A., Perez-Aguirre C. & Assmann T. (2012). A new method for collecting agile tiger beetles by live pitfall trapping. *Entomologia Experimentalis et Applicata* **145**: 82 – 87.  
DOI: <https://doi.org/10.1111/j.1570-7458.2012.01316.x>
- Tanner V.M. (1951). Notes on some Cicindelidae of the western United States and the South Pacific Islands with a description of a new species. *Great Basin Naturalist* **11**(1): 47 – 51.
- Tennent J.E. (1860). *Ceylon: An Account of the Island, Physical, Historical and Topographical with Notices of its Natural History, Antiquities and Productions*. Longman and Roberts, London, UK.
- Thotagamuwa A., Dangalle C.D., Pallewatta N. & Lokupitiya E. (2016). Selection of tiger beetle species as potential bioindicator organisms for coastal ecosystems of Sri Lanka. *Proceedings of the Annual Research Symposium 2016*, University of Colombo, Sri Lanka, pp. 295.
- Toki W., Pham H.T. & Hori M. (2017). Pupa of an arboreal tiger beetle, *Neocollyris similis* (Lense) (Coleoptera: Carabidae: Cicindelinae), from the internode cavity of a reed. *The Coleopterists Bulletin* **71**(1): 202 – 203.  
DOI: <https://doi.org/10.1649/0010-065X-71.1.202>
- Trautner J. & Schawaller W. (1996). Larval morphology, biology and faunistics of Cicindelidae (Coleoptera) from Leyte, Philippines. *Tropical Zoology* **9**: 47 – 59.  
DOI: <https://doi.org/10.1080/03946975.1996.10539302>
- Wiesner J. & Bandinelli A. (2014). Notes on the tiger beetles (Coleoptera: Cicindelidae) of Argentina. 117. Contribution towards the knowledge of Cicindelidae. *Insecta Mundi* **0377**: 1 – 66.
- Wilcove D.S., Rothstein D., Dubow J., Phillips A. & Losos E. (1998). Quantifying threats to imperiled species in the United States. *BioScience* **48**(8): 607 – 615.  
DOI: <https://doi.org/10.2307/1313420>
- Whiting M.J., Chetty K., Twine W. & Carazo P. (2009). Impact of human disturbance and beliefs on the tree agama *Acanthocercus atricollis atricollis* in a South African communal settlement. *Oryx* **43**(4): 586 – 590.  
DOI: <https://doi.org/10.1017/S0030605309990160>
- Wu X.-Q. & Shook G. (2007). Range extensions, new records, an artificial key and a list of tiger beetles of Yunnan Province, China (Coleoptera: Cicindelidae). *Journal of the Entomological Research Society* **9**(2): 31 – 40.