JoTT Communication 3(2): 1493-1505

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

Chandima Dangalle [1], Nirmalie Pallewatta [2] & Alfried Vogler [3]

[1,2] Department of Zoology, Faculty of Science, University of Colombo, Colombo 03, Sri Lanka
[3] Department of Entomology, The Natural History Museum, London SW7 5BD, United Kingdom
Email: [1] cddangalle@yahoo.com (corresponding author), [2] nirmalip@yahoo.com, [3] a.vogler@nhm.ac.uk

Date of publication (online): 26 February 2011
Date of publication (print): 26 February 2011
ISSN 0974-7907 (online) | 0974-7893 (print)

Editor: K.A. Subramanian

Manuscript details:
Ms # o2501
Received 02 July 2010
Final received 29 December 2010
Finally accepted 05 January 2011

Citation: Dangalle, C., N. Pallewatta & A. Vogler (2011). 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.

Author Details, Acknowledgments: see end of this article.

Author contribution: CD conducted field studies in Sri Lanka and laboratory work in the Natural History Museum, London, U.K. She contributed towards research design and methodology and writing of the paper. NP contributed towards formulating the initial concept, research design and methodology and writing of the paper. AV contributed by formulating the initial concept and molecular sequencing methodology and analyses.

Abstract: The current occurrence, habitat and historical change in distributional range are studied for an endemic tiger beetle species, *Cicindela (Ifasina) willeyi* Horn of Sri Lanka. At present, the species is only recorded from Maha Oya (Dehi Owita) and Handapangoda, and is absent from the locations where it previously occurred. The current habitat of the species is explained using abiotic environmental factors of the climate and soil recorded using standard methods. Morphology of the species is described by studying specimens using identification keys for the genus and comparing with specimens available at the National Museum of Colombo, Sri Lanka. The DNA barcode of the species is elucidated using the mitochondrial CO1 gene sequence of eight specimens of *Cicindela (Ifasina) willeyi*. The study suggests that Maha Oya (Dehi Owita) and Handapangoda are suitable habitats. However, its presence in only two locations and its absence from locations where it previously occurred highlights the need for conserving the natural habitats at Maha Oya (Dehi Owita) and Handapangoda, and the necessity of further studies of this kind.

Keywords: Conservation, DNA barcode, habitat preferences, taxonomy, tiger beetles.

INTRODUCTION

Tiger Beetles (Coleoptera: Cicindelidae) are a group of attractive, fast-flying and fast-running insect predators that occur in many diverse habitats around the world (Pearson & Cassola 2007). The ease with which most species can be found and identified in the field, their habitat specificity and their value as indicators of habitat health and biodiversity have generated considerable interest among amateurs and professional biologists alike (Pearson & Cassola 2007). As a result, a total of 2,559 species have been described world wide since the first eight cicindelid species were identified by Carl Von Linné in the 18th century (Pearson & Cassola 2005). Most tiger beetle species (29% of described species) are found in the Oriental (Indo-Malaysian) region of the world, while northeastern India has the highest recorded number of species in a small area which is an 80km stretch between Siliguri and Darjeeling of West Bengal (Pearson 1988; Pearson & Cassola 2005). Sri Lanka is also attributed with a high number of cicindelid species and ranks amongst the top 30 countries of the world with the highest number of species (Cassola & Pearson 2000).

The existing literature (Tennent 1860; Horn 1904; Fowler 1912; Naviaux 1984; Acciavatti & Pearson 1989), and collections available at the National Museum of Colombo and Natural History Museum of London, documents 54 species of tiger beetles from Sri Lanka belonging to five genera (Table 1), *Cicindela, Tricondyla, Derocrania,*

Table 1. The Cicindelidae of Sri Lanka according to the existing literature

	Genus: Subgenus	Species	Locality
1	***Collyris***	*Collyris dohrni* Chaudoir, 1860	Trincomalee, Haldummulle, Paranthan, Odduchuddan, Colombo
2	***Neocollyris***	*Neocollyris planifrons* Horn, 1905	Wellawaya
3		*Neocollyris punctatella* Chaudoir, 1864	Balangoda
4		*Neocollyris saundersi* Chaudoir, 1864	Kanthalai, Bandarawela, Kandy, Wellawaya, Trincomalee, Peradeniya
5		*Neocollyris crassicornis* Dejean, 1825	Elephant Pass
6		*Neocollyris plicaticollis* Chaudoir, 1864	Urugalla
7		*Neocollyris andrewesi* Horn, 1894	
8		*Neocollyris ceylonica* Chaudoir, 1864	Bogawantalawa
9	***Tricondyla***	*Tricondyla coriacea* Chevrolat, 1841	Kanthalai, Horowpatana, Urugalla, Mankulam, Trincomalee, Neerodumunai, Olumadu, Kekirawa, Palatupana, Chilaw, Ella, Wellawaya, Kandy, Tirukkovil
10		*Tricondyla granulifera* Motschulsky, 1857	Urugalla, Homagama, Haragam, Nalanda, Kandy
11		*Tricondyla nigripalpis* Horn, 1894	Kongawella, Central Ceylon
12	***Derocrania***	*Derocrania agnes* Horn, 1905	
13		*Derocrania nietneri* Motschulsky, 1859	Urugalla, Rakwana, Bulutota, Balangoda, Bandarawela, Bogawantalawa, Nuwara Eliya, Nalanda, Kandy
14		*Derocrania fusiformis* Horn, 1904	
15		*Derocrania gibbiceps* Chaudoir, 1860	Urugalla, Nalanda, Central Ceylon
16		*Derocrania concinna* Chaudoir, 1860	Urugalla, Kandy, Balangoda, Rakwana, Nalanda, Puttalam
17		*Derocrania schaumi* Horn, 1892	Trincomalee, Hambantota, Kandy, Kekirawa
18		*Derocrania halyi* Horn, 1900	Anuradhapura, Pankulam, Kanthalai, Trincomalee, Puttalam
19		*Derocrania scitiscabra* Walker, 1859	Urugalla, Horowpatana, Trincomalee, Badulla, Tamblegam, Galgamuwa, Uva province, Belihul Oya, Haldummulla, Sigiriya, Nalanda, Kandy
20		*Derocrania nematodes* Schaum, 1863	Bogawantalawa, Central Ceylon
21	***Cicindela:*** *Ifasina*	*Cicindela willeyi* Horn, 1904	Central Province, Labugama
22		*Cicindela waterhousei* Horn, 1900	Labugama, Kitulgala, Karawanella, Avissawella
23		*Cicindela dormeri* Horn, 1898	Kitulgala, Labugama, Kandy, Peradeniya, Haragama, Udawattakele Sanctuary
24		*Cicindela ganglbaueri* Horn, 1892	Rakwana, Ratnapura, Kanneliya, Labugama
25		*Cicindela henryi* Horn, 1925	Minneriya, Horowpatana, Kala Oya, Kataragama
26		*Cicindela labioaenea* Horn, 1892	Wariyapola, Kandy, Horowpatana, Kotte, Battaramulla, Kanneliya forest, Kitulgala, Udugama, Wellawaya, Miyanapalawa, Labugama, Puttalam, Negombo, Yatiyantota, Peradeniya, Nalanda, Weligama, Hatton, Karawanella, Avissawella, Matugama, Opanake, Ratnapura, Kegalla, Weddagala, Nittambuwa, Kurunegala, Udawattakele, Pompakele, Ambalamahena
27		*Cicindela nietneri* Horn, 1894	Kurunegala
28	*Oligoma*	*Cicindela lacunosa* Putzeys, 1875	Andankulam, Horowpatana, Mullativu, Koggala, Habarana, Minneriya, Hatton, Wellawaya, Wavuniya, Wilpattu National Park, Anuradhapura, Kandy, Puttalam, Kataragama, Lahugala, Tissamaharama, Kurunegala, Kala Oya
29		*Cicindela paradoxa* Horn, 1892	Puttalam, Matale, Negombo, Colombo Museum Garden, Weligama, Hendala, Kitulgala, Matugama, Weddagala, Yatiyantota
30	*Jansenia*	*Cicindela corticata* Putzeys, 1875	Andankulam, Koggala, Minneriya, Habarana, Hambantota, Peradeniya, Kataragama, Uggalkaltota, Wavulpane, Maduvanwala, Angunakolapelessa, Kala Oya
31		*Cicindela westermanni* Schaum, 1861	
32		*Cicindela laeticolor* Horn, 1904	Trincomalee, Hambantota

	Genus: Subgenus	Species	Locality
33		*Cicindela cirrihidia*	Cockmuttai, Jaffna, Anuradhapura, Wilpattu National Park
34		*Cicindela stellata*	Trincomalee
35	*Myriochile*	*Cicindela distinguenda* Dejean, 1825	Elephant Pass, Hambantota, Anuradhapura, Puttalam, Padaviya, Kilinochchi, Mannar
36		*Cicindela undulata* Dejean, 1825	Galgamuwa, Andankulam, Colombo, Tissamaharama, Puttalam, Lahugala, Kala Oya
37	*Monelica*	*Cicindela fastidiosa* Dejean, 1825	Mankulam, Andankulam, Koggala, Elephant Pass, Habarana, Hambantota, Haldummulle, Eppawala, Trincomalee, Wilpattu National Park, Anuradhapura, Tissamaharama, Puttalam, Lahugala, Kala Oya
38	*Lophyridia*	*Cicindela angulata* Fabricius, 1798	Mannar District, Pesalai, Talaimannar, Hendala, Anuradhapura, Chilaw, Sigiriya, Kurunegala, Mahaweli ganga, Kalkudah, Puttalam, Godakewela, Arugam Bay, Deduru Oya, Colombo, Yala
39		*Cicindela cardoni* Fleutiaux, 1890	Maduru Oya, Punani, Chilaw, Mahaweli Ganga, East Polonnaruwa, Kurunegala, Kegalla
40	*Calochroa*	*Cicindela discrepans* Walker,1858	Wellawaya, Horowpatana, Kandy, Colombo, Habarana, Sigiriya, Anuradhapura, Badulla, Hambantota, Kataragama, Nalanda, Kitulgala, Kala Oya
41		*Cicindela haemorrhoidalis* Wiedemann, 1823	Horowpatana, Anuradhapura, Kataragama, Haragama, Eppawala, Wellawaya, Sigiriya
42		*Cicindela sexpunctata* Fabricius, 1775	Jaffna, Maha Oya, Sigiriya, Puttalam District, Wellawaya
43		*Cicindela aurovittata* Audouin & Brullé, 1839	Maha Oya, Puttalam, Mundal, Kalkudah, Deduru Oya
44		*Cicindela lacrymans* Schaum, 1863	Labugama, Kandy, Kelani Valley, Kottawa, Kanneliya, Ratnapura, Udawattakele Sanctuary, Gilimale, Kitulgala
45	*Ancylia*	*Cicindela ceylonensis* Horn, 1892	Wellawaya, Pulmoddai, Moneragala, Trincomalee
46		*Cicindela calligramma* Schaum, 1861	Puttalam District, Palugassegama
47		*Cicindela diversa* Horn, 1904	Anuradhapura, Giritale, Mannar, Wilpattu National Park, Cockmuttai
48	*Lophyra*	*Cicindela fuliginosa* Dejean, 1826	
49		*Cicindela catena* Fabricius, 1775	Miyanapalawa, Colombo, Matale, Kandy, Hendala, Labugama, Kitulgala, Bentota, Matugama, Kurunegala, Puttalam, Kala Oya, Weddagala, Kataragama, Kandachchi, Aluthgama, Jaffna, Dolosbage, Trincomalee, Hambantota
50	*Cosmodela*	*Cicindela aurulenta* Fabricius, 1801	
51	*Hypaetha*	*Cicindela quadrilineata* Fabricius, 1781	Marichchakkaddi, Colombo
52		*Cicindela biramosa* Fabricius, 1781	Mannar, Mount Lavinia, Colombo Trincomalee, Weligama, Delft, Hendala, Kalutara, Nilaweli, Kalkudah, Pottuvil, Pesalai, Galle, Kelani Valley
53	*Callytron*	*Cicindela limosa* Saunders, 1834	Puttalam, Iranativu, Chilaw
54	*Eugrapha*	*Cicindela singalensis* Horn, 1911	Hambantota

Collyris and *Neocollyris*. The majority of species are included in the genus *Cicindela* which consists of 13 subgenera, *Ancylia, Calochroa, Lophyra, Lophyridia, Jansenia, Oligoma, Cosmodela, Eugrapha, Monelica, Myriochile, Hypaetha, Callytron* and *Ifasina* (Table 1). Subgenus *Ifasina* is attributed with the highest number of species (7) out of which five species are endemic to the island.

We report in this paper the first recorded occurrence of an endemic tiger beetle species, *Cicindela (Ifasina) willeyi*, from two locations of Sri Lanka and the habitat preferences of the species.

METHODS AND MATERIALS

Tiger beetles were surveyed in 94 localities of Sri Lanka from May 2002 to December 2005 (Fig. 1,

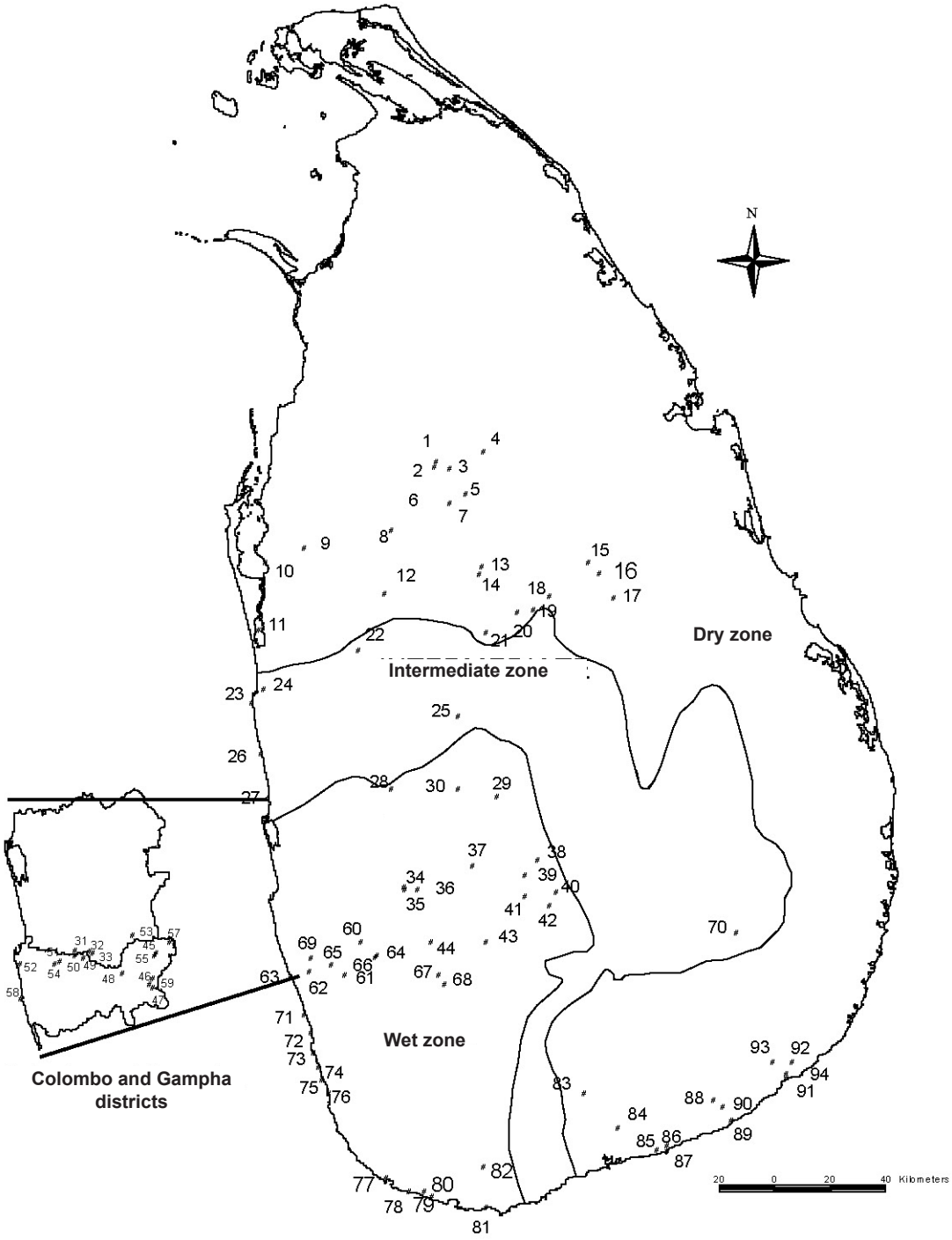

Figure 1. Localities of Sri Lanka surveyed for the occurrence of tiger beetles (Place names of localities are provided in Table 2)

Table 2). The localities for collecting tiger beetles were selected using information based on previous publications of cicindelid species of Sri Lanka and information based on the different habitat types of the family on a global scale.

Field studies were conducted at Maha Oya (Dehi Owita) in August 2003 and 2004, and at Handapangoda in July 2003 and 2004.

Study Area: Maha Oya is a stream located at Dehi Owita ($6^0$57'91"N & $80^0$16'44"E, elevation 6.7m) in the Kegalle District, Sabaragamuwa Province of Sri Lanka. It covers an area of 17km^2 and encompasses

Table 2. Localities of Sri Lanka surveyed for the occurrence of tiger beetles

Location Number	Place Name
1	Abhaya Wewa, Anuradhapura
2	Thisa Wewa, Anuradhapura
3	Nuwara Wewa, Anuradhapura
4	Mahakanadarawa Wewa, Anuradhapura
5	Nachchaduwa Wewa, Anuradhapura
6	Talawa Tank, Talawa
7	Turuwila Wewa, Anuradhapura
8	Rajangana Reservoir, Tambuttegama
9	Tabbowa Wewa, Karuwalagaswewa
10	Puttalam Lagoon, Puttalam
11	Mundel Lake, Puttalam
12	Kurundankulama Tank, Anuradhapura
13	Kala Wewa, Anuradhapura
14	Balalu Wewa, Anuradhapura
15	Minneriya Wewa, Polonnaruwa
16	Giritale Wewa, Polonnaruwa
17	Parakrama Samudra, Polonnaruwa
18	Sigiriya, Matale District
19	Kandalama Tank, Dambulla
20	Dambulu Oya, Dambulla
21	Dewahuwa Wewa, Dambulla
22	Magalla Tank, Nikaweratiya
23	Chilaw Coast, Chilaw
24	Deduru Oya, Halawatha
25	Batalegoda Tank, Ibbagamuwa
26	Marawila Coast, Marawila
27	Porutota Coast, Negombo
28	Ma Oya, Alawwa
29	Meewatura, Peradeniya
30	Ma Oya, Mawanella
31	Biyagama, Gampaha
32	Kimbulawila Wewa, Malwana
33	Seethawaka River, Thalduwa
34	Maha Oya Falls, Dehi Owita
35	Maha Oya, Dehi Owita
36	Kahanawita Falls, Dehi Owita
37	We Oya, Yatiyantota
38	Ramboda Falls, Ramboda
39	Pundalu Oya, Talawakele
40	Silver Falls, Nuwaraeliya
41	Kotmale Oya, Talawakele
42	Dessford Falls, Talawakele
43	Adams Peak, Ratnapura
44	Bopath Falls, Ratnapura
45	Water Canal, Labugama
46	Water Canal, Puwakpitiya
47	Kumari Falls, Thummodara

Location Number	Place Name
48	Heen Ela, Waga
49	Kelani Rriver, Kaduwela
50	Kelani River, Kirielamulla
51	Angoda, Colombo
52	National Museum Garden, Colombo
53	Kelani River, Malwana
54	Pugoda Ferry, Kosgama
55	Malabe, Colombo
56	Ranwala Ferry, Awissawella
57	Pahuru Wila, Malwana
58	Aswathu Oya, Awissawella
59	Mount Lavinia Beach
60	Wak Oya, Thummodara
61	Water Canal, Handapangoda
62	Water Canal, Horana
63	Mahabellana Ferry
64	Thalpitiya, Wadduwa
65	Nachchimale, Horana
66	Kalu Ganga Bank, Horana
67	Kalu Ganga, Ingiriya
68	Gammanpila Tank, Bandaragama
69	Katugasella Falls, Ratnapura
70	Maragalakanda, Moneragala
71	Irahandapana Falls, Ratnapura
72	Katukurunda Coast, Kalutata
73	Maggona Coast, Maggona
74	Aluthgama Coast, Aluthgama
75	Induruwa Coast, Induruwa
76	Kosgoda Beach, Kosgoda
77	Galle Harbour, Galle
78	Morampitigoda Coast, Morampitigoda
79	Habaraduwa Beach, Habaraduwa
80	Kataluwa Coast, Koggala
81	Matara Beach, Matara
82	Enselwatta, Sinharaja
83	Kollewa Dola, Sinharaja
84	Chandrika Wewa, Embilipitiya
85	Ridiyagama Wewa, Ambalantota
86	Karagan Salterns, Hambantota
87	Hambantota Salterns, Hambantota
88	Hambantota Beach, Hambantota
89	Tissa Wewa, Tissamaharama
90	Kirinda Beach, Kirinda
91	Yoda Wewa, Tissamaharama
92	Menik Ganga, Kataragama
93	Salterns, Yala
94	Sellakataragama, Kataragama

the Grama Niladhari divisions of Dehi Owita, Debagama and Thimbiripola. The stream is a branch of the much larger Kelani River which starts from the Sri Pada Mountain range and flows in to the ocean at Colombo. The water of Maha Oya is slow flowing and runs parallel to a large sandy bank with 167m elevation (Fig. 2 & Image 1).

The stream at Handapangoda ($6^0$47'05N & $80^0$08'03E; elevation 23m) is located near a rubber estate in the Kalutara District, Western Province of Sri Lanka. It covers an area of 11km^2 and encompasses the Grama Niladhari divisions of Handapangoda, Arakawila, Menerigama and Kurana. It is a branch of Kalu Ganga, which is the second largest river of Sri Lanka and is restricted entirely to the wet zone of the country. The water of the stream is slow flowing and runs parallel to a narrow sandy bank that consists mostly of rocks (Fig. 2 & Image 2).

Collection of Beetles: Four visits were made to each site for surveying adult tiger beetles. Three belts of land of 100 to 150 m were selected on the sandy bank of Maha Oya, while two belts were selected on the bank of Handapangoda. All sites were sampled over five hours each day between 1000 to 1400 hr.

Beetles were searched for in specific habitats and their immediate surroundings e.g. shrub area near the sandy sections of the stream, rocky substrata, pathways and trails. When encountered tiger beetles were rapidly counted at a given site using a hand tally counter (Wagtech, UK) and a sample was collected using a standard insect net. The number of beetles and the sex ratio of those that could be observed under field conditions and from collected specimens were recorded.

Specimens were collected and preserved in 96% ethanol and stored at -20^{0}C for subsequent identification.

Measuring Habitat Variables: The following habitat variables of the study sites were recorded.

(i) Weather variables: The ambient temperature, degree of solar radiation, relative humidity and wind speed of the habitat were recorded using a portable integrated weather station (Health EnviroMonitor, Davis Instrument Corp., Hayward, CA, USA) with optional sensors.

(ii) Soil characteristics: These included the soil group (determined by using the generalized soil map of Sri Lanka by Moorman & Panabokke 1961);

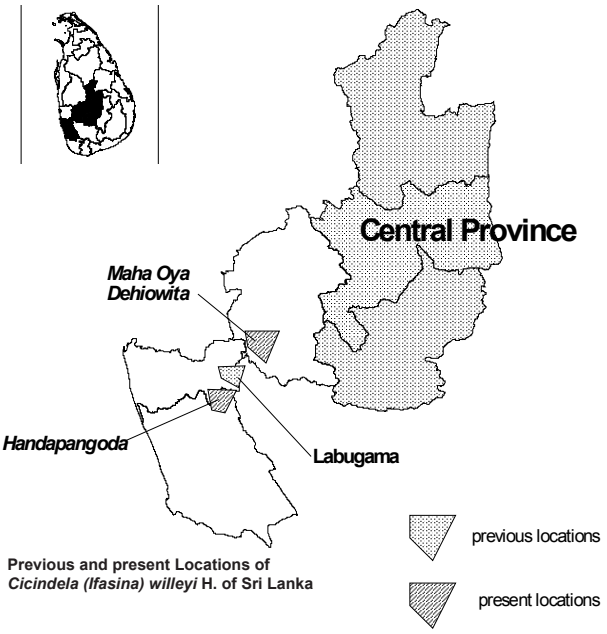

Figure 2. Study area at Maha Oya and Handapangoda with previous locations

Image 1. Maha Oya (Dehi Owita)

Image 2. Stream at Handapangoda

soil type / texture (determined by the sedimentation technique using the "soil textural triangle" as the reference (Bierman 2007)); soil colour (measured by comparison with a Munsell soil colour chart); soil temperature (determined by using an insert soil thermometer (SG 680-10) ranging from –10 to 110 ^{0}C); soil pH (determined by using a portable soil pH meter (Westminster, No.259)); soil moisture (determined by selecting five random spots of a locality and collecting samples down to a depth of 10cm and estimating the difference in weight before and after oven drying to 107 to 120 ^{0}C in the laboratory.); soil salinity (determined by a YSI model 30 hand-held salinity meter).

Determination of morphological characteristics of tiger beetles: Morphological characters important in identification and for the purpose of establishing characteristics of this species were also noted as follows.

(i) Body weight: Each beetle was weighed to the nearest mg on an analytical balance (Chyo JL180, Chyo Balance Corp., Japan).

(ii) Body length: Estimated by measuring the length from the frons of the head to the elytral apex when the head was in the normal feeding position. The spines on the caudal end of the elytra were disregarded. Measurements were taken using a dissecting microscope (Nikon Corporation SE., Japan) with the aid of an eyepiece graticule (Nikon, Tokyo, Japan) calibrated by an objective micrometer (Olympus, Japan).

Body lengths of beetles were categorized as follows, based on size classes relevant for this group of insects (Acciavatti & Pearson 1989).

1. very small – less than 8mm
2. small – 8 to 10 mm
3. medium – 10 to 15 mm
4. large – 15 to 20 mm
5. very large – more than 20mm

(iii) Mandible length / chord: The distance from the articulation point of the left mandible to the tip were measured under a dissecting microscope (Nikon Corporation SE, Japan) with the aid of an eyepiece graticule (Nikon, Tokyo, Japan) calibrated by an objective micrometer (Olympus, Japan). Only specimens with undamaged or not noticeably worn mandibles were used (Pearson & Juliano 1993; Satoh & Hori 2004).

(iv) Other characters: In addition to the above characters the following features were also recorded for each specimen.

1. Colouration – Dorsal and ventral colouration of the body and its metallic or iridescent appearance was noted as was the colour of the elytral maculae, pits, eyes, antennae, mandibles, labrum and legs.
2. Number of rugae between eye and vertex.
3. Labrum – The shape of the labrum and the number of labral setae.
4. Distribution of setae on body.
5. Distribution of pits on body.

The above characters were observed under a photomicrographic attachment (Microflex AFX – DX, Nikon Corporation, Tokyo, Japan) which was also used in photographing each specimen (dorsal view, ventral view, lateral view, other important features). Additional photographs of species were also taken by using the computer software programme Auto Montage (facilitated with a SMC Pentax – FA macro camera) available at the entomology laboratory of the Natural History Museum, London.

Taxonomic keys of the *Cicindela* of the Indian subcontinent by Acciavatti & Pearson (1989), descriptions of Horn, (1904) and Fowler (1912) were used to identify the species and confirmation of identification was done through comparisons with specimens available at the National Museum of Colombo.

DNA Sequencing: DNA analysis was carried out to determine the DNA barcode of the species. Eight specimens from the two known populations (Maha Oya and Handapangoda) were used for DNA extraction and sequencing. DNA was extracted from the abdominal region of the beetle using the DNeasy protocol (July 2003). Voucher specimens were deposited in the Entomology Collection of the Department of Zoology, University of Colombo.

A ~810 bp region of the 3' end of the cytochrome oxidase 1 (CO1) gene was amplified using primers M202 (forward, 5' - CAA CAT TTA TTT TGA TTT TTT GG - 3', alias Jerry; Simon et al. 1994) and M70 (reverse, 5' - TCC ATT GCA CTA ATC TGC CAT ATT A - 3', alias Pat; Simon et al. 1994).

Standard PCR amplifications included 5µl of NH_4 buffer, 0.5µl of each dNTP, 1µl of each primer, 0.1µl of TAQ polymerase and 2.5µl of $MgCl_2$ in a 50µl reaction volume. PCR amplifications were carried out on a GeneAmp PCR System 9700 thermal cycler

(Applied Biosystems, California, USA) for one cycle of (94^{0}C, 2.5 mins.; 47^{0}C, 0.5 mins.; 72ºC, 11 mins.; 4^{0}C, α) for 40 cycles. The PCR products were purified using the UltraClean PCR clean-up DNA purification kit (MoBio Laboratories Inc., Carlsbad, CA, USA) according to the manufacturer's protocol.

Sequencing was performed for 10µl of cleaned PCR product using the ABI Prism Big Dye Terminator Cycle sequencing kit (PE Applied Biosystems, Foster City, CA, USA). PCR primers were used as sequencing primers and each fragment was sequenced on both strands. The reaction products were purified by ethanol precipitation and sequenced on ABI 373 (version 3.0) automated DNA sequencer. Sequence files were edited using SEQUED version 1.0.3 (Applied Biosystems) and a consensus of bidirectional sequencing was determined.

RESULTS

Cicindela (Ifasina) willeyi H. was the only tiger beetle species observed at Maha Oya (Dehi Owita) and Handapangoda. Fifty beetles of *Cicindela (Ifasina) willeyi*. were observed from Maha Oya (Dehi Owita) and five beetles were collected for morphometric and morphological characterization. Ten specimens of the species were recorded from Handapangoda and three were collected for characterization.

Taxonomy of *Cicindela (Ifasina) willeyi* Horn, 1904: The description given in Horn (1904), Fowler (1912) and Acciavatti & Pearson (1989) and the specimens available at the National Museum, Colombo matches the features observed in the specimens collected from Maha Oya (Dehi Owita) and Handapangoda sites.

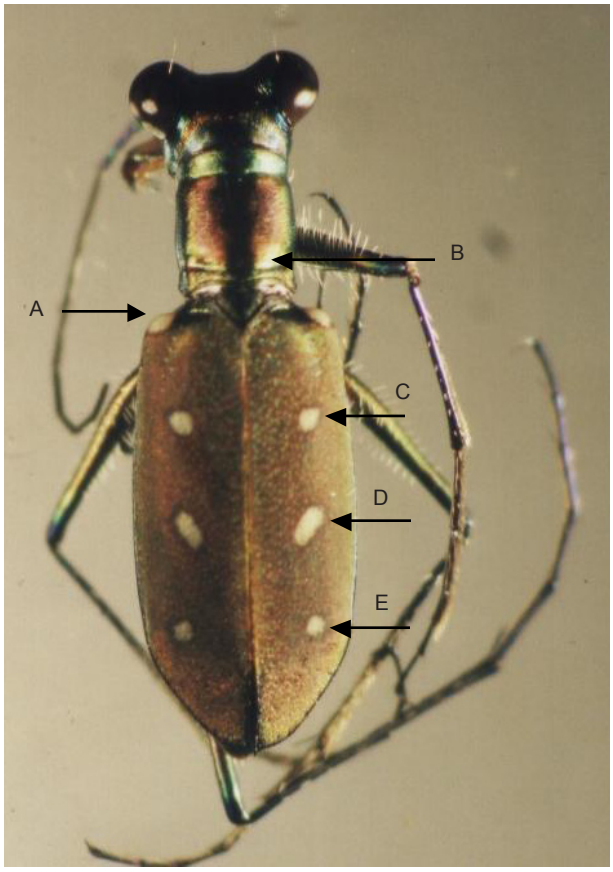

Image 3. *Cicindela (Ifasina) willeyi* Horn, 1904 female , habitus, dorsal view (total length = 9.2 mm) (x10 x 1.0)
A - Elytral humeral spot; B - Pronotum; C - First elytral spot; D - Second elytral spot; E - Third elytral spot

Diagnosis: *Cicindela (Ifasina) willeyi* H. closely resembles the other allied species *C. (I.) waterhousei*

Table 3. Morphometric parameters of *Cicindela (Ifasina) willeyi* Horn collected from Maha Oya (Dehi Owita) and Handapangoda

Specimen No.	Body Length (mm)	Body Weight (mg)	Left Mandible Length (mm)
BMNH(E)703891	9.45	32.3	1.63
BMNH(E)703898	8.68	23.4	Damaged
BMNH(E)703899	9.35	27.8	Damaged
BMNH(E)703900	9.40	31.2	1.88
BMNH(E)703901	9.60	31.3	Damaged
BMNH(E)703902	8.88	25.5	Damaged
BMNH(E)703903	9.00	23.1	Damaged
BMNH(E)703904	9.20	24.7	2.20
Average	**9.19 ± 0.56**	**27.45 ± 1.94**	**1.90 ± 0.54**

Table 4. Climatic conditions at Maha Oya (Dehi Owita) and Handapangoda

Parameter	Maha Oya (Dehi Owita)	Handapangoda
Temperature	32ºC	32ºC
Relative humidity	65%	65%
Solar radiation	132 W/m^2	126 W/m^2
Barometric pressure	760 Hgmm	760 Hgmm
Wind speed	0ms^{-1}	0ms^{-1}
Wind direction	South-West	South-West

Table 5. Soil conditions at Maha Oya (Dehi Owita) and Handapangoda

Parameter	Maha Oya (Dehi Owita)	Handapangoda
Soil group	Red-Yellow Podzolic soil	Red-Yellow Podzolic soil
Soil type	Sand	Sand
Soil colour	Yellowish-brown (10YR5/6)	Dark yellowish-brown (10YR4/6)
Soil temperature	28ºC	27ºC
Soil pH	6.8	6.0
Soil moisture	2.89%	17.96%

Horn, *C. (I.) dormeri* Horn and *C. (I.) ganglbaueri* Horn that are also endemic to Sri Lanka. However, the species can be distinguished by the presence of an elytral humeral dot and three spots that lie medially in a line on elytra; more excavate forehead between the eyes; narrow, conical pronotum with a dorsal bulge that is undivided by a short medial line (Image 3).

Description: Body small with an average length of 9.19 ± 0.56 mm and an average body weight of 27.45 ± 1.94 mg (n = 8) (Table 3). Dorsal region of head, pronotum and base of eyes shiny copper green in colour. Elytra metallic brown with a humeral dot, and three spots medially in a line. Spots yellowish-white in colour. First and third spot circular and small. Middle spot large, ovate or pear-shaped. Ventral side

DNA Barcode (consensus sequence of CO1 gene) of *Cicindela (Ifasina) willeyi* H. (GenBank Accession Number: HM600780)

TTTGGGATAATTTCACATATTATCAGCCAAGAAAGAGGTAAAAAGGAAACATTTGGATCATTG
GGYATAATTTACGCTATATTAGCAATTGGRTTATTAGGATTTGTAGTTTGAGCTCATCATATAT
TTACTGTAGGAATAGATGTAGACACTCGRGCCTACTTCACCTCTGCCACTATAATTATTGCTGT
ACCAACAGGYATTAAAATTTTTTCATGACTMGCCACACTTCATGGATCTCAAATTTCTTACAG
ACCYTCTCTATTGTGAGCCTTGGGATTTGTATTCCTATTCACTGTGGGRGGYCTAACTGGRGTA
GTATTAGCAAATTCATCAATTGATATTATCCTTCATGATACATATTATGTAGTTGCYCATTTTC
ACTACGTTCTATCAATAGGRGCAGTATTCGCAATTATATCAGGATTTATCCAATGATTCCCATT
ATTTACAGGATTAACTATGAACAATAGCTTRCTTAAAATTCAATTTATAATTATATTTGTGGGG
GTTAATCTTACATTCTTCCCTCAACATTTCCTAGGATTAAGAGGGATACCTCGTCGGTACTCAG
ACTACCCTGATGCTTATGTTTCATGAAATATYGTATCATCTATTGGCTCAACTATTTCGTTCAT
TGGTGTATTAATGCTAATTTATATTATTTGAGAAAGATTTTCATCTCAACGCCTMGTRCTATTC
CCTAATCAAATATCYACATCTATTGAATGATTCCAAAATATTCCCCCCGCTGAGCATAGTTACT
CAGAACTT

Table 6. Historical change in distribution of *Cicindela (Ifasina) willeyi* with relevance to decline in geographic range.

Species	Past Locations	Approximate Area (km^2)	Present Locations	Approximate Area (km^2)	Decline in Geographic Range (km^2)	Past Habitats	Present Habitats	Population Size
Cicindela (*Ifasina*) *willeyi*	Central Province; Labugama, Western Province	5575 8.5	Maha Oya, Dehi Owita, Sabaragamuwa Province; Handapangoda, Western Province	17 11	5555.5	Unknown	Riparian. On the sandy banks of river / stream.	Past – Unknown. Maha Oya 50 beetles were observed in the area. Handapangoda 10 beetles were observed in the area.

of body iridescent bluish-green with white setae. Labrum short, broad and brown in colour with eight or nine submarginal setae. Mandibles dark brown with left mandible having an average length of 1.90 ± 0.54 mm (n = 3). Pronotum with a medial dorsal bulge that is undivided by a medial line. Legs shiny blue-green in colour (Image 3).

Habitat of *C. (I.) willeyi*: Beetles were found on a sandy bank at Maha Oya (Dehi Owita) which is a shallow stream found in the Sabaragamuwa Province. The periphery of the sandy bank consisted of shrub type vegetation of Gahala *Colocasia esculenta*, Bamboo *Bambusa vulgaris* and long grasses that provided shade to the habitat. Climatic and soil conditions of the site are given in Tables 4 and 5.

The climatic and soil conditions at Handapangoda were more or less similar to that of Maha Oya (Dehi Owita) (Tables 4 & 5). However, the beetles at Handapangoda were mainly found on the moist rocks on the sandy bank. Further, the habitat at Handapangoda was more better shaded than that at Maha Oya due to the large trees found on the bank.

Historical change in distribution of *C. (I.) willeyi*: The species has been reported from the Central Province of the island and Labugama, Western Province from as far back as 1904 (Horn 1904; Fowler 1912; Acciavatti & Pearson 1989; collection of the National Museum of Colombo, Sri Lanka). However, it has not been studied thereafter, and although it's biology is well known, data on present distribution and habitat is lacking. According to the results of the current study, at present it occupies two habitats in Maha Oya (Dehi Owita) area and Handapangoda area. Investigations in the present study have further revealed that the species is absent from its former locations of Central Province and Labugama which have a geographical area of about 5583.5km^2 and is now restricted to an area of about 28km^2 in Maha Oya (Dehi Owita) and Handapangoda (Table 6).

Therefore, a loss of its present habitats where it is restricted in distribution may threaten the survival of the species and qualify it for a threatened category in the near future.

DISCUSSION

Cicindela (Ifasina) willeyi is an endemic tiger beetle species of Sri Lanka that was first described by Horn (1904) from the Central province of Sri Lanka, which was subsequently confirmed by Fowler (1912) and later by Acciavatti & Pearson (1989). The National Museum of Colombo houses a specimen of the species collected from Labugama in the Western Province of the country. However, the present distribution of this endemic species has been uncertain and habitat characteristics and preferences were completely unknown. The present study reveals the species from Maha Oya (Dehi Owita) (Sabaragamuwa Province), and Handapangoda (Western Province), localities from which it had not been previously recorded. Further, extensive field work carried out in riparian habitats of *Meewathura*, Kandy; *Ma Oya*, Mawanella; *Pundalu Oya, Kotmale Oya, Ramboda* and *Silverfalls*, Nuwara Eliya (Central Province); and Labugama (Western Province) during the study period confirms the absence of the species from its previous localities of occurrence (Fig. 1). This knowledge on the past and present distribution of *C. (I.) willeyi* indicates the possibility of a historical change in the distributional range of the species.

Various factors including urbanization, increased intensity of recreational use of beaches, increased off-road vehicle traffic, conversion of the habitat to a dumping ground for automobile parts and construction material, increased vegetation encroachment that eliminates open areas and inundation of habitat caused by the construction of dams have been used to explain historical range changes in tiger beetles in the United States (Knisley & Hill 1992; Kritsky et al. 1996; Knisley & Fenster 2005; Pearson et al. 2006; Simmons 2007).

Therefore, it is possible that *C. (I.) willeyi* extirpated from the localities in the Central Province and Labugama, and inhabited the area in Handapangoda and Maha Oya (Dehi Owita). Even though, the reason for this is not precisely known, possible events of the past can be suggested.

The Mahaweli Development Programme was initiated in Sri Lanka in 1979 to fulfill the water requirements for agriculture, industrial and domestic use, develop hydropower and reduce flood peaks. As a result of this programme, four major reservoirs and

dams, namely, Kotmale, Victoria, Randenigala and Rantambe were built along the main stem of the river that lies in the Central Province (Dayawansa 2008). Building of a dam is known to reduce and corrode soil and rock along the river as massive deposits of soil are left within the reservoir. The massive cobblestones, sand and crushed stones held back by the dam and the transformation of the once tortuous riverbank and riverway to a relatively straight river course results in the loss of habitat for many invertebrates who survive in this environment (Mao & Zheng 2006). During reservoir filling the river and any associated wetland areas become inundated. Riffles, runs and pools of the river are lost beneath the rising waters, leading to the extirpation (or extinction) of habitat sensitive riverine species with tightly defined niche requirements (McAllister et al. 2001). Likewise, reservoir and dam construction along the Mahaweli River has resulted a considerable impact on river morphology and has inundated a vast area of land in the Central Province of the island. Aerial photographs obtained in 1985 and 2003, and topographical maps of the Survey Department of Sri Lanka, present encroachments towards the river across its floodplain area in Gohagoda, Central Province. Further, riparian areas in Peradeniya (Central Province) have changed to residential urban areas with considerable impacts of waste disposal (Dayawansa 2008).

It is also recorded that gold has been mined in the past from a concordant quartz reef in Central Sri Lanka (Nawaratne & Dissanayake 2001), and several gemming grounds are located in Nuwara Eliya, Horton Plains, Hatton and Kandy (Herath 1984).

Therefore, it is strongly possible that *C. (I.) willeyi* went locally extinct from its historic sites in the Central Province of Sri Lanka and invaded the riparian habitats of Maha Oya (Dehi Owita) (Sabaragamuwa Province) and Handapangoda (Western Province) due to the unsuitability and loss of its former habitats. The presence of populations of the species at Maha Oya and Handapangoda, indicate the suitability of the habitat, climate and soil conditions of these locations.

Tiger beetles are known to prefer riverine habitats because of close proximity to food and water resources, safety from predators and reasonably low human disturbance (Bhargav & Uniyal 2008). Shade of the habitat is used as an oviposition cue for many species and clusters of larval burrows were found near the bases of plants in *Cicindela cursitans* Le Conte, of Ohio Valley, United States (Brust et al. 2005).

Further, their activity and density are greatly influenced by daily temperature patterns (Schultz 1983), and adult tiger beetles are known to maintain internal body temperatures that are just below their lethal limits of 39^{0}C (Pearson et al. 2006). A ground temperature ranging from 32-33 ^{0}C is known to be suitable for the activity and viability of tiger beetle populations, and a temperature of 34-35 ^{0}C determined the greatest number of matings in *Cicindela (Cephalota) circumdata leonschaeferi* Cassola (Eusebi et al. 1989).

Tiger beetles prefer sandy soils with minimal vegetation, where periodic disturbance by wind and water removes encroaching vegetation (Warren & Buttner 2008). Colour patterns of adult tiger beetle species closely match the texture and hue of the soil substrate on which the species occurs (Pearson & Vogler 2001), and matching the body colour with that of the soil plays an important role in predator evasion by reducing discovery (Morgan et al. 2000).

The habitats at Maha Oya (Dehi Owita) and Handapangoda were both riparian with sparse vegetation that consisted of shrubs. In Handapangoda, ferns and bamboo were found on the stream banks providing shade to the habitat while a similar habitat was also found at Maha Oya. Ground temperature were similar at both sites and were at 32^{0}C, while the soil temperature was 28^{0}C at Maha Oya, and 27^{0}C at Handapangoda. Both river banks consisted of soil with a sandy texture that was yellowish-brown at Maha Oya and dark yellowish-brown at Handapangoda. The colour of soil at both sites closely matched the colour of beetles, that were metallic brown dorsally with yellow-white maculations.

As *C. (I.) willeyi* is an endemic species with limited distribution and is consequently susceptible to local extinction, it is important that these habitats are identified and protected. At present, 99.5% of its distributional range has declined (Table 6). We believe that the most important conservation priority of a country is the protection of areas which house large numbers of endemic species and communities found nowhere else in the world. This study presents first evidence and importance of Maha Oya (Dehi Owita) and Handapangoda locations, as harbouring the only populations of an endemic species of tiger beetles. In

view of the current human use of all of these sites and habitats and the development pressures exerted on the wet zone of the country, conservation of these sites are essential for future survival of this species.

REFERENCES

Acciavatti, R.E. & D.L. Pearson (1989). *The Tiger Beetle Genus Cicindela (Coleoptera, Insecta) from the Indian Subcontinent*. Annals of Carnegie Museum No. 58, Pensylvania, 353pp.

Bhargav, V.K. & V.P. Uniyal (2008). Communal roosting of tiger beetles (Cicindelidae: Coleoptera) in the Shivalik Hills, Himachal Pradesh, India. *Cicindela* 40(1-2): 1-12.

Bierman, P. (2007). Management Solutions to Soil Limitations. State Master Gardener Conference, Department of Soil, Water and Climate, University of Minnesota, 9pp.

Brust, M., W.W. Hoback & C.B. Knisley (2005). Biology, habitat preference, and larval description of *Cicindela curtisans* Leconte (Coleoptera: Carabidae: Cicindelinae). *The Coleopterists Bulletin* 59(3): 379-390.

Cassola, F. & D.L. Pearson (2000). Global patterns of tiger beetle species richness (Coleoptera: Cicindelidae) their use in conservation planning. *Biological Conservation* 95: 197-208.

Dayawansa, N.D.K. (2008). Assessment of changing pattern of the river course and its impact on adjacent riparian areas highlighting the importance of multi-temporal remotely sensed data. Proceedings of the Asian Conference on Remote Sensing, Colombo, Sri Lanka.

Eusebi, M.P., L. Favilli & S. Lovari (1989). Some abiotic factors affecting the activity and habitat choice of the tiger beetle *Cephalota circumdata leonschaeferi* (Cassola) (Coleoptera, Cicindelidae). *Italian Journal of Zoology* 56(2): 143-150.

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, 529pp.

Herath, J.W. (1984). Geology and Occurrence of Gems in Sri Lanka. *The Journal of the National Science Council of Sri Lanka* 12(2): 257-271.

Horn, W. (1904). The Cicindelidae of Ceylon. *Spolia Zeylanica* 2(5): 30-45.

Knisley, C.B. & M.S. Fenster (2005). Apparent extinction of the tiger beetle, *Cicindela hirticollis abrupta* (Coleoptera: Carabidae: Cicindelinae). *The Coleopterists Bulletin* 59(4): 451-458.

Knisley, C.B. & J.M. Hill (1992). Effects of habitat change from ecological succession and human impact on tiger beetles. *Virginia Journal of Science* 43(1): 133-142.

Kritsky, G., L. Horner, S. Reidel & A.J. Savage (1996). The status of some tiger beetles (Coleoptera: Cicindelidae: Cicindela spp.) in Southern Ohio. *Ohio Journal of Science* 96(1): 29-30.

Mao, C. & R. Zheng (2006). Analysis of impacts of dams on ecological environment of river ecosystem, pp. 1135-1142. In: Berga L., J.M. Boil, E. Bofill, J.C. De Cea, J.A.G. Perez, G. Manueco, J. Polimon, A. Soriano, J. Yague (eds.). *Dams and Reservoirs, Societies and Environment in the 21st Century*. Taylor & Francis Group, London, 1144pp.

McAllister, D.E., J.F. Craig, N. Davidson, S. Delany, & M. Seddon (2001). Biodiversity impacts of large dams. *IUCN/UNEP/WCD Background Paper* 1: 12-47.

Moorman, F.R. & C.R. Panabokke (1961). Soils of Ceylon: a new approach to the identification and classification of the soils of Ceylon. *Tropical Agriculture* 117: 4-65.

Morgan, M., C.B. Knisley & A.P. Vogler (2000). New taxonomic status of the endangered tiger beetle *Cicindela limbata albissima* (Coleoptera: Cicindelidae): Evidence from mtDNA. *Ecology and Population Biology* 93(5): 1108-1115.

Naviaux, R. (1984). Coleoptera, Cicindelidae. Les Cicindelés de Sri Lanka. *Revue Scientifique Du Bourbonnais* 57-80.

Nawaratne, C.B. & C.B. Dissanayake (2001). Gold occurrences in Madagascar, South India and Sri Lanka: Significance of a possible Pan-African event. *Gondwana Research* 4(3): 367-375.

Pearson, D.L. & F. Cassola (2005). A quantitative analysis of species descriptions of tiger beetles (Coleoptera: Cicindelidae), from 1758 to 2004, and notes about related developments in biodiversity studies. *The Coleopterists Bulletin* 59(2): 184-193.

Pearson, D.L. & F. Cassola (2007). Are we doomed to repeat history? A model of the past using tiger beetles (Coleoptera: Cicindelidae) and conservation biology to anticipate the future. *Journal of Insect Conservation* 11: 47-59.

Pearson, D.L. & A.P. Vogler (2001). *Tiger Beetles: The Diversity, Ecology and Evolution of the Cicindelidae*. Cornell University Press, Ithaca, New York, 333pp.

Pearson, D.L. (1988). Biology of tiger beetles. *Annual Review of Entomology* 33: 123-147.

Pearson, D.L., C.B. Knisley & C.J. Kazilek (2006). *A Field Guide to the Tiger Beetles of the United State and Canada: Identification, Natural History and Distribution of the Cicindelidae*. Oxford University Press, Oxford, New York, 227pp.

Pearson, D.L. & S.A. Juliano (1993). Evidence for the influence of historical processes in co-occurrence and diversity of tiger beetle species, pp. 194-202. In: Ricklefs, R.E. & D. Schulter (eds.). *Species Diversity in Ecological Communities*. Chicago University Press, Chicago, USA.

Satoh, A. & M. Hori (2004). Interpopulation differences in the mandible size of the coastal tiger beetle *Lophyridia angulata* associated with different sympatric species. *Entomological Science* 7: 211-217.

Schultz, T.D. (1983). Opportunistic foraging of western kingbirds on aggregations of tiger beetles. *Auk* 100: 496-497.

Simon, C., F. Frati, A. Beckenbach, B. Crespi, H. Liu & P.

Flock (1994). Evolution, weighting and phylogenetic utility of mitochondrial gene sequences and a compilation of conserved polymerase chain reaction primers. *Annals of the Entomological Society of America* 87: 651-701.

Simmons, T. (2007). Natural Heritage & Endangered Species Program. Division of Fisheries & Wildlife, Westborough¸ MA.

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, 631pp.

Warren, S.D. & R. Buttner (2008). Active military training areas as refugia for disturbance-dependent endangered insects. *Journal of Insect Conservation* 12: 671-676.

Author Details: Dr. Chandima Dangalle is a senior lecturer in Zoology. Her expertise lies in the fields of entomology and molecular biology. Her research focuses on collecting baseline data on the distribution and habitat preferences of tiger beetles in Sri Lanka and in evolution and phylogeny of the species. Dr. Dangalle conducted her PhD in the Department of Zoology, University of Colombo, Sri Lanka and Department of Entomology, Natural History Museum, London, United Kingdom.

Dr. Nirmalie Pallewatta is a senior lecturer and the current head of the Department of Zoology, University of Colombo, Sri Lanka. A zoologist by training Dr. Pallewatta received her Ph.D. in 1986 from the Imperial College of Science, Technology and Medicine at the University of London, U.K.

Dr. Alfried Vogler works on the molecular systematics of Coleoptera. He has a joint position at the Natural History Museum and at Imperial College, London, U.K. Together with PhD students and postdocs, he is currently studying basal relationships of Scarabaeinae and Aphodiinae. He is also interested in the factors determining the composition of dung beetle communities and the effect of species interactions on the evolution of ecomorphological diversity.

Acknowledgements: We wish to thank the Department of Wildlife Conservation, Ministry of Environment, Sri Lanka for providing permits necessary for field work and export of specimens. We are grateful to Prof. Nimal Dangalle, Department of Geography, University of Kelaniya, Sri Lanka for his assistance in the preparation of maps and locational lists. This work has been supported by grant number RG/2003/ZOO/01 from the National Science Foundation of Sri Lanka.