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Predicting the relationship between body size and habitat type of tiger beetles (Coleoptera, Cicindelidae) using Artificial Neural Networks

Heshani M. Edirisinghe[1], Chandima D. Dangalle[2]* and Koliya Pulasinghe[3]

[1]*Department of Plant Sciences, Faculty of Science, University of Colombo, Cumaratunga Munidasa Mawatha, Colombo 03, Sri Lanka.*
[2]*Department of Zoology, Faculty of Science, University of Colombo, Cumaratunga Munidasa Mawatha, Colombo 03, Sri Lanka.*
[3]*Faculty of Graduate Studies, Sri Lanka Institute of Information Technology, New Kandy Road, Malabe, Sri Lanka.*

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ABSTRACT

Tiger beetles are considered as important bioindicators due to many features and specificity to habitat types of the group. Species specificity to habitat types are associated with their preference for oviposition site, prey choice, predator evasion, tolerance to flooding and inundation, climate and soil conditions of the environment. The present study was carried out to investigate the association between habitat type and body size of tiger beetles and to predict habitat type using body size and habitat parameters as classifiers. One hundred nineteen tiger beetles were collected from various habitat types of the country and one hundred nineteen data sets including body length and twelve parameters of the habitat were used for the analysis. Artificial neural networks were constructed using multi-layer perceptron and radial basis function approximation methods and two optimal networks were selected to confirm the association. The networks revealed an association between habitat type and body size of tiger beetles that was significant in reservoir and urban habitat type and evident in riverine and coastal habitats. The association was dependent on habitat parameters of the locations and a non-linear relationship was evident between body size and habitat parameters. Multiple classifiers obtained from the networks were used to construct a software tool with a graphical user interface for predicting habitat type of tiger beetle species.

Key Words: Tiger beetle, body size, habitat type, relationship, artificial neural networks.

INTRODUCTION

Tiger beetles are predatory insects that are found in many countries of the world (Pearson 1988). They are ideal bioindicators that characterize ecosystems of open areas and forests (Adis *et al.* 1998), biodiversity (Knisley 2011), endemism (Pearson & Ghorpade 1989), abundance of certain other taxa (Pearson & Cassola 1992), disturbance of habitats (Bhardwaj *et al.* 2008, Knisley 2011) and degradation and regeneration of tropical forests (Rodriguez *et al.* 1998). Distribution of tiger beetles in many biogeog--raphic areas and habitat types, knowledge on diversity and ecology, well-known stable taxonomy and most importantly habitat specificity has contributed to their success as an essential indicator taxa (Pearson & Cassola 2007). Tiger beetles are highly habitat specific and each species rarely occurs in more than one or a very few habitat types (Morgan *et al.* 2000, Satoh *et al.* 2004, Cardoso & Vogler 2005, Rafi *et al.* 2010). The association of tiger beetle species with habitat has been related to their preferences for oviposition sites (Cornelisse & Hafernik 2009); vegetation cover (Pearson *et al.* 2006); climatic conditions – air temperature, relative humidity (Dreisig 1980); soil conditions – soil

Corresponding author: cddangalle@gmail.com

structure, soil moisture, soil temperature, soil colour (Dreisig 1980, Morgan *et al.* 2000, Cornelisse & Hafernik 2009); prey choice (Cardoso & Vogler 2005); predator evasion (Morgan *et al.* 2000, Cardoso & Vogler 2005) and tolerance to flooding and inundation (Brust *et al.* 2006). However, the association of morphological characters of tiger beetles with habitat type has not been studied, even though they have been measured for many species of various habitats. The tiger beetles of Sri Lanka are highly habitat specific (Dangalle *et al.* 2012a). Species are restricted to four habitat types – beach and coastal, reservoir, stream and river bank, man-made urban habitats. The association of species with habitat type has been related with climatic conditions – solar radiation, wind velocity; and soil conditions – soil moisture, soil pH, soil salinity of the environment (Dangalle *et al.* 2012). Further, for the first time an association between body size of species with habitat type and conditions have been shown. Tiger beetle species with larger body sizes were shown to prefer coastal and reservoir habitats with high wind speed, low soil moisture and high soil pH, whereas species with smaller body sizes were shown to prefer riverine and urban habitats with low wind speed, high soil moisture and low soil pH (Dangalle *et al.* 2013). However, the study utilizing thirteen habitat parameters and analysed using statistical procedures were unable to demonstrate the habitat types in which the habitat type – body size relationship between tiger beetles were more pronounced, habitat parameters that significantly affected the relationship and the type of relationship between habitat parameters and body size.

Artificial Neural Networks (ANNs) are computing systems that are designed to solve problems in pattern recognition, prediction, optimization, associative memory and control (Jain *et al.* 1996). They are different from conventional computing systems because of their wide range of applicability and the case with which they can treat complicated problems. Artificial neural networks can identify and learn correlated patterns between input data sets and corresponding target values and after training can be used to predict the output of new independent input data. As they imitate the learning process of the animal brain, artificial neural networks are ideally suited for the modeling of ecological data which are known to be complex and often non-linear. At present, two popular artificial neural networks are used, (i) multi-layer feed-forward neural network trained by backpropagation algorithm, (ii) Kohonen self-organizing mapping (Lek & Guegan 1999). The multi-layer feed-forward neural network is based on a supervised procedure in which the network constructs a model based on examples of data with known outputs. Kohonen self-organizing mapping falls into the category of unsupervised learning methodology, in which the relevant multivariate algorithms seek clusters in the data. In the present study we intend to develop a multi-layer feed-forward network for predicting the relationship between the body size and habitat type of tiger beetles, to determine the habitat parameters that are more important in determining the above relationship, to determine the relationship between habitat parameters and body size and habitat type in which the relationship is more accurately classified. By using artificial neural networks, multiple classifiers for predicting habitat type would be selected and a tool with a graphical user interface will be developed for predicting habitat type.

MATERIALS AND METHODS

Investigations for tiger beetles were conducted in ninety-four locations of Sri Lanka from May 2002 to December 2006. Coastal areas, river banks, reservoir banks, agricultural lands, forests, marshlands and urban areas were investigated in the wet, intermediate and dry zones of the country. When beetles were encountered a sample of three to five beetles were collected using a standard insect net and preserved in 70% alcohol for morphometric analysis.

Measurement of body size

The body size of tiger beetles was estimated by measuring the body length of the beetle. Body length was 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 were disregarded. Measurements were taken using a dissecting microscope (Nikon Corporation SE, Japan) calibrated by an objective micrometer (Olympus, Japan). Based on the references of Acciavatti & Pearson (1989), McCairns *et al.* (1997) and Zerm & Adis (2001), the body length of tiger beetles was categorized as follows:

Less than 8 mm: Very small
8 – 10 mm: Small
10 – 15 mm: Medium
15 – 20 mm: Large
More than 20 mm: Very large

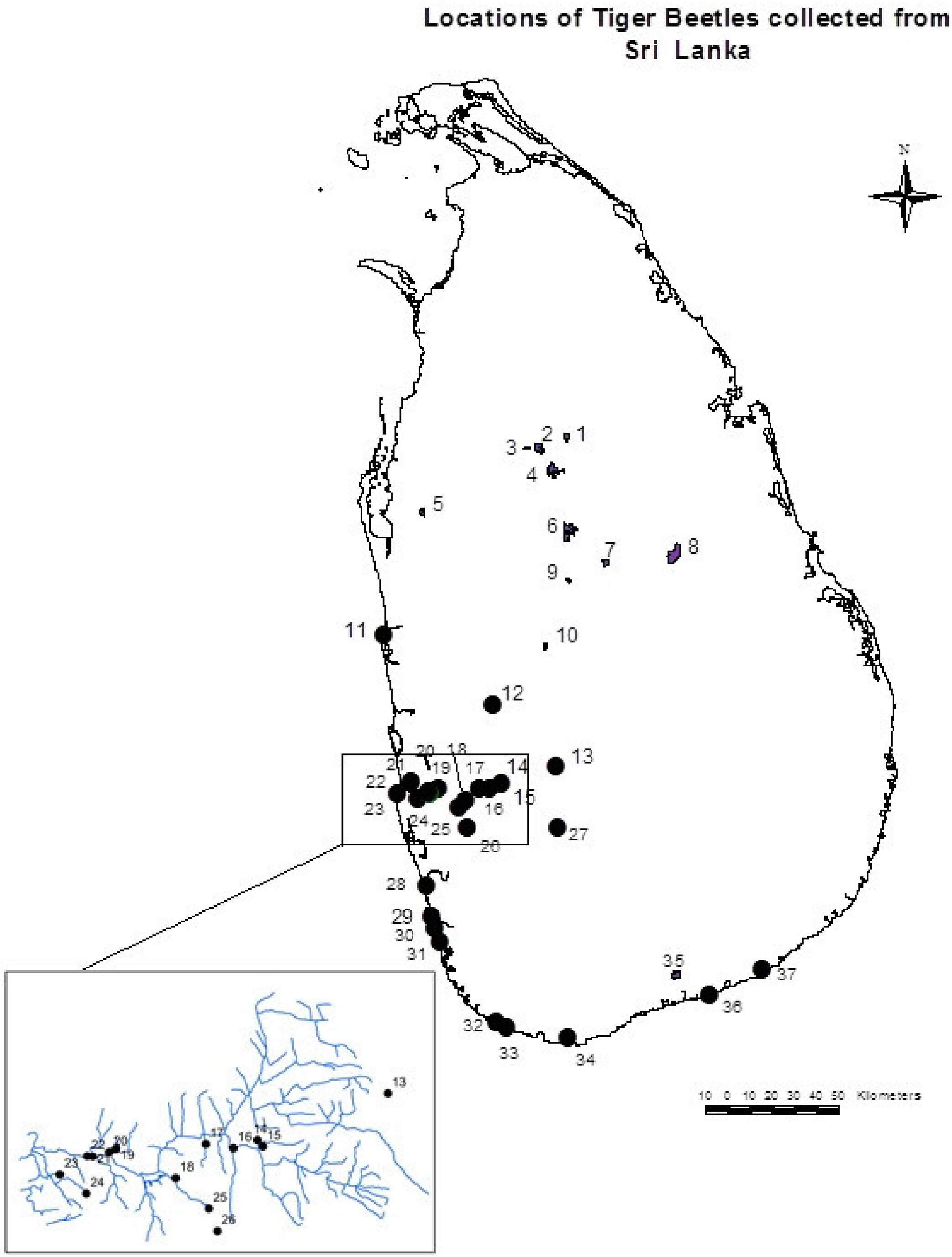

Fig. 1. Sampling locations of tiger beetles

Measurement of habitat parameters

The following habitat parameters of the sampling locations of tiger beetles were determined using the method stated.

(i) Elevation – Determined using a geographical positioning system device (GPS 315, Magellan systems Corp., Taiwan).

(ii) Air temperature and Relative humidity – Measured using the external temperature / humidity sensor of a portable integrated weather station (Health EnviroMonitor, Davis Instrument Corp., USA).

(iii) Solar radiation - Measured using the solar radiation sensor of the portable integrated weather station.

(iv) Wind speed - Measured using the anemometer of the portable integrated weather station.

(v) Soil type - Determined by the sedimentation technique using the "soil textural triangle".

(vi) Soil colour – Measured by comparison with a Munsell soil colour chart (Year 2000 revised washable edition).

(vii) Soil temperature - Determined using a soil thermometer (Insert Thermometer, SG 680-10).

(viii) Soil moisture - Determined by selecting five random spots of a locality and collecting samples to a depth of 10 cm and estimating the difference in weight before and after oven drying to 107-120°C in the laboratory.

(ix) Soil pH - Determined using a portable soil pH meter (Westminster, No.259).

(x) Soil salinity - Determined using a YSI model 30 hand-held salinity meter.

Data preprocessing

A sample of 119 data sets, each consisting of 13 variables – body length, habitat type, elevation, air temperature, relative humidity, solar radiation, wind speed, soil type, soil colour, soil temperature, soil moisture, soil pH, soil salinity were used for the analysis. Data sets were randomized using Ms Excel 2007 software package and imported to Matlab (R2008b) software package for processing. The non-numerical variables, soil type and soil colour, were converted to numerical values, while habitat type was converted to a numerical value and boolean type value. The 119 data sets were divided into three categories, training data set (89), validation data set (06) and test data set (24).

Creating networks

Networks with different architectures were built using multi-layer perceptron and radial basis function approximation methods. In multi-layer perceptron, the training data set was trained in trial and error method by changing the input variable, number of hidden layers, number of hidden neurons and transfer function. Input variables were changed by using either all thirteen (13) variables, body length, body length with one other habitat parameter. The validation data set was used to evaluate the generalization capacity of the networks and test data set was used to evaluate the fitness of the classifier.

Radial basis function approximation was carried out by changing the input variables. The number of hidden layers, hidden neurons and approximation function were selected automatically by the programme.

Evaluation of the performance of networks

The performance of the networks was evaluated using the mean squared error, confusion matrix and receiver operating characteristic (ROC) curve. In receiver operating characteristic curve, the area under the curve (AUC) provided a measure of the networks accuracy as stated below by Hosmer and Lemeshow (2000).

If AUC = 0.5 → No discrimination
If 0.7 ≤ AUC < 0.8 → Acceptable discrimination
If 0.8 ≤ AUC < 0.9 → Excellent discrimination
If AUC ≥ 0.9 → Outstanding discrimination

Development of a predicting tool

A graphical user interface (GUI) for predicting habitat type of tiger beetles using body length and habitat parameters as classifiers was developed using Matlab (R2008 release).

RESULTS

Tiger beetles were found in thirty-seven locations of Sri Lanka in coastal, riverine, reservoir and urban habitat types (Fig. 1 and Table1). One hundred nineteen (119) beetles belonging to five genera and ten species were collected from the locations (Table 1).

Body size of tiger beetles

Tiger beetles collected during the study were very small (less than 8 mm), small (8 – 10 mm) and medium (10 -15 mm) in body size. Species of genus *Cylindera* were very small or small, while species of

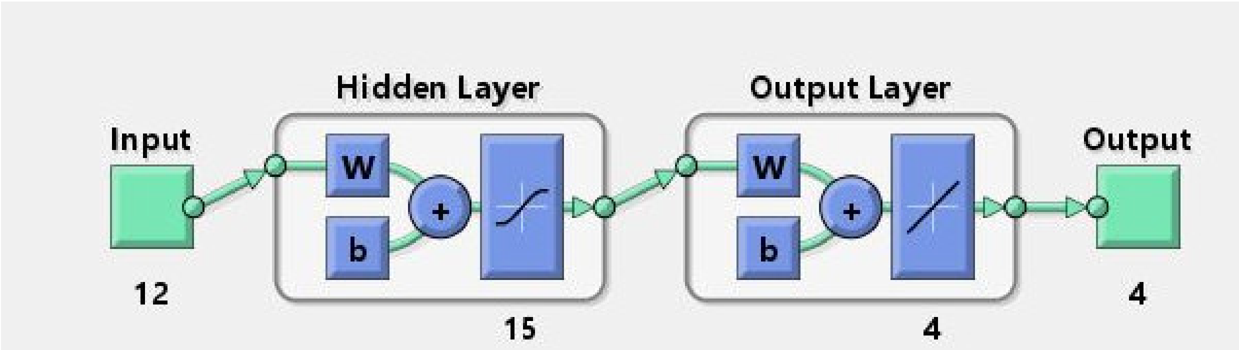

Fig. 2. Optimum network obtained by multi-layer perceptron method

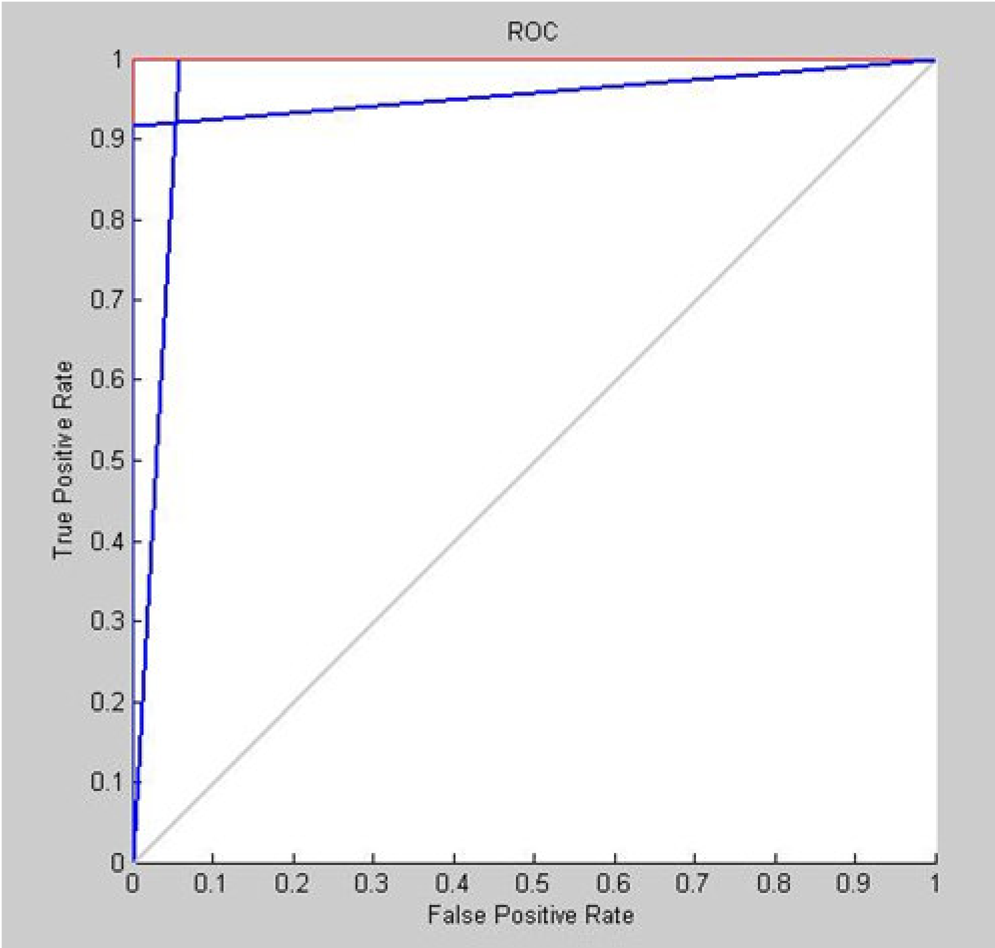

Fig. 3. The Receiver Operating Curve (ROC) for multi-layer perceptron optimum network

Table 1. Locations, habitat types and body sizes of tiger beetle species collected during the study (Location number coincides with the number given for the location in Figure 1)

Location	Habitat type	Species collected	Number of specimens collected	Body length range (mm)	Body size
1. Mahakanadarawa Wewa, Anuradhapura district, North-Central province	Reservoir	*Calomera angulata*	03	10.75 – 12.50	Medium
2. Nuwara Wewa, Anuradhapura district, North-Central province	Reservoir	*Myriochila* (*Monelica*) *fastidiosa*	02	12.00 – 12.60	Medium
3. Thisa Wewa, Anuradhapura district, North-Central province	Reservoir	*Calomera angulata*	05	10.55 – 12.50	Medium
4. Nachchaduwa Wewa, Anuradhapura district, North-Central province	Reservoir	*Myriochila* (*Monelica*) *fastidiosa* *Calomera angulata*	03 01	11.00 – 12.40 10.48	Medium Medium
5. Tabbowa Wewa, Karuwalagaswewa, Puttalam district, North-Western province	Reservoir	*Myriochila* (*Monelica*) *fastidiosa* *Calomera angulata*	03 02	11.20 – 11.90 10.63 – 12.10	Medium Medium
6. Kala Wewa, Anuradhapura district, North-Central province	Reservoir	*Calomera angulata*	03	10.13 – 11.15	Medium
7. Kandalama Wewa, Dambulla, Matale district, Central province	Reservoir	*Myriochila* (*Monelica*) *fastidiosa* *Calomera angulata*	02 02	11.20 – 11.28 10.88 – 12.80	Medium Medium
8. Parakrama Samudra, Polonnaruwa district, North-Central proivnce	Reservoir	*Calomera angulata*	03	11.08 – 11.70	Medium
9. Devahuwa Wewa, Dambulla, Matale district, Central province	Reservoir	*Lophyra* (*Lophyra*) *catena* *Cylindera* (*Oligoma*) *lacunosa* *Calomera angulata*	01 01 03	11.40 8.10 11.08 – 12.50	Medium Small Medium
10. Batalagoda Wewa, Kurunegala district, North-Western province	Reservoir	*Calomera angulata*	03	10.05 – 11.30	Medium
11. Halawatha, Puttalam district, North-Western province	Coastal	*Lophyra* (*Lophyra*) *catena*	04	11.28 – 12.00	Medium
12. Ma Oya, Alawwa, Kurunegala district, North-Western province	Riverine	*Calomera cardoni* *Calomera angulata*	03 01	11.70 – 14.00 10.55	Medium Medium
13. We Oya, Yatiyantota, Kegalle district, Sabaragamuwa province	Riverine	*Cylindera* (*Ifasina*) *labioaenea*	03	7.10 – 7.30	Very small
14. Maha Oya, Dehi Ovita, Kegalle district, Sabaragamuwa province	Riverine	*Cylindera* (*Ifasina*) *willeyi*	07	8.68 – 9.60	Small

Table 1 contd...

15. Maha Oya Falls, Dehi Ovita, Kegalle district, Sabaragamuwa province	Riverine	*Cylindera* (*Ifasina*) *labioaenea*	03	7.30 – 8.00	Very small to Small
16. Seethavaka River, Thalduwa, Colombo district, Western province	Riverine	*Cylindera* (*Ifasina*) *labioaenea*	01	7.83	Very small
17. Asvathu Oya, Awissawella, Colombo district, Western province	Riverine	*Cylindera* (*Ifasina*) *labioaenea*	04	7.28 – 8.30	Very small to Small
18. Heen Ela, Waga, Colombo district, Western province	Riverine	*Cylindera* (*Ifasina*) *labioaenea*	01	7.65	Very small
19. Kelani River, Malwana, Gampaha district, Western province	Riverine	*Cylindera* (*Ifasina*) *labioaenea*	03	8.28 – 8.70	Small
20. Kelani River, Kirielamulla, Gampaha district, Western province	Riverine	*Cylindera* (*Ifasina*) *labioaenea*	02	8.60 – 8.90	Small
21. Kelani River, Kaduwela, Colombo district, Western province	Riverine	*Cylindera* (*Ifasina*) *labioaenea*	02	8.00	Small
22. Biyagama, Gampaha district, Western province	Riverine	*Cylindera* (*Ifasina*) *labioaenea*	01	8.13	Small
23. National Museum, Colombo district, Western province	Urban	*Lophyra* (*Lophyra*) *catena* *Cylindera* (*Oligoma*) *paradoxa*	02 04	11.23 – 11.25 7.38 – 8.00	Medium Very small to Small
24. Angoda, Colombo district, Western province	Urban	*Cylindera* (*Ifasina*) *labioaenea*	01	9.30	Small
25. Thummodara, Colombo district, Western province	Riverine	*Cylindera* (*Ifasina*) *labioaenea*	01	7.05	Very small
26. Handapangoda, Kalutara district, Western province	Riverine	*Cylindera* (*Ifasina*) *willeyi* *Cylindera* (*Ifasina*) *waterhousei*	01 02	9.45 7.55 – 9.90	Small Very small to Small
27. Bopath Ella, Ratnapura district, Sabaragamuwa province	Riverine	*Cylindera* (*Ifasina*) *waterhousei*	05	8.53 – 9.08	Small
28. Katukurunda, Kalutara district, Western province	Coastal	*Lophyra* (*Lophyra*) *catena*	04	10.70 – 11.80	Medium
29. Aluthgama, Kalutara district, Western province	Coastal	*Lophyra* (*Lophyra*) *catena*	02	11.50 – 12.30	Medium
30. Induruwa, Galle district, Southern province	Coastal	*Hypaetha biramosa*	04	11.25 – 12.50	Medium
31. Kosgoda, Galle district, Southern province	Coastal	*Hypaetha biramosa*	04	11.25 – 13.30	Medium
32. Morampitigoda, Galle district, Southern province	Coastal	*Hypaetha biramosa*	03	11.60 – 12.80	Medium
33. Habaraduwa, Galle district, Southern province	Coastal	*Hypaetha biramosa*	02	12.90 – 13.63	Medium
34. Matara, Matara district, Southern province	Coastal	*Hypaetha biramosa*	03	10.50 – 12.00	Medium
35. Ridiyagama Wewa, Ambalantota, Hambantota district, Southern province	Reservoir	*Lophyra* (*Lophyra*) *catena*	01	10.25	Medium
36. Hambantota, Hambantota district, Southern province	Coastal	*Myriochila* (*Monelica*) *fastidiosa*	03	10.38 – 12.30	Medium
37. Kirinda, Hambantota district, Southern province	Coastal	*Lophyra* (*Lophyra*) *catena*	05	10.48 – 11.10	Medium

Table 2. Habitat parameters of the sampling locations of tiger beetles.

Location	**Elevation (m)**	**Air temperature (°C)**	**Relative humidity (%)**	**Solar radiation (w/m^2)**	**Wind speed (MPH)**	**Soil type**	**Soil colour**	**Soil temperature (°C)**	**Soil moisture (%)**	**Soil pH**	**Soil salinity (ppt)**
Mahakanadarawa Wewa, Anuradhapura district, North-Central province	85.04	31	60	64	17	Sandy	Very dark grayish brown	28	9.14	7.1	0.00
Nuwara Wewa, Anuradhapura district, North-Central province	80.69	34	47	159	21	Sandy	Black	33	0.35	6.9	0.00
Thisa Wewa, Anuradhapura district, North-Central province	79.86	34	48	736	4	Sandy	Yellow	31	0.12	6.7	0.00
Nachchaduwa Wewa, Anuradhapura district, North-Central province	96.01	32.8	53	256	10	Sandy	Dark yellowish brown	33	7.94	7.0	0.00
Tabbowa Wewa, Karuwalagaswewa, Puttalam district, North-Western province	20.42	39	41	206	7	Sandy	Light olive brown	34.5	3.65	7.0	0.00
Kala Wewa, Anuradhapura district, North-Central province	125.88	38.5	52	618	6	Sandy	Light olive brown	32	0.64	7.0	0.00
Kandalama Wewa, Dambulla, Matale district, Central province	176.52	33	58	56	9	Sandy	Brownish yellow	33	5.20	8.0	0.00
Parakrama Samudra, Polonnaruwa district, North-Central proivnce	56.69	29.5	63	64	3	Sandy	Light yellowish brown	30	0.148	7.5	0.00
Devahuwa Wewa, Dambulla, Matale district, Central province	181.66	37	40	363	4	Sandy	Reddish yellow	38.5	0.13	6.8	0.00
Batalagoda Wewa, Kurunegala district, North-Western province	131.98	35.2	47	655	0	Sandy	Yellowish brown	42.5	11.49	6.8	0.00

Table 2 contd...

Location	**Elevation (m)**	**Air temperature (°C)**	**Relative humidity (%)**	**Solar radiation (w/m^2)**	**Wind speed (MPH)**	**Soil type**	**Soil colour**	**Soil temperature (°C)**	**Soil moisture (%)**	**Soil pH**	**Soil salinity (ppt)**
Halawatha, Puttalam district, North-Western province	0.00	41	45	245	22	Sandy	Yellowish brown	35.5	0.18	-	0.00
Ma Oya, Alawwa, Kurunegala district, North-Western province	45.11	32	66	248	2	Sandy	Yellowish brown	29	1.67	7.1	0.00
We Oya, Yatiyantota, Kegalle district, Sabaragamuwa province	31.0	38.6	53	222	0	Sandy	Strong brown	37	8.513	7.0	0.00
Maha Oya, Dehi Ovita, Kegalle district, Sabaragamuwa province	6.71	32	65	132	0	Sandy	Yellowish brown	28	2.89	6.8	0.00
Maha Oya Falls, Dehi Ovita, Kegalle district, Sabaragamuwa province	39.3	34	59	232	0	Rocks	-	-	-	-	-
Seethavaka River, Thalduwa, Colombo district, Western province	13.1	36	58	947	0	Sandy	Dark yellowish brown	32.5	12.08	6.4	0.00
Asvathu Oya, Awissawella, Colombo district, Western province	16.5	33	66	714	4	Sandy	Yellowish brown	31	3.198	6.4	0.00
Heen Ela, Waga, Colombo district, Western province	18.3	36.4	49	495	0	Sandy	Strong brown	33	13.95	4.6	0.00
Kelani River, Malwana, Gampaha district, Western province	23.2	38	53	578	0	Muddy	Dark brown	31	52.21	4.4	0.00

Table 2 contd...

Location	**Elevation (m)**	**Air temperature (°C)**	**Relative humidity (%)**	**Solar radiation (w/m^2)**	**Wind speed (MPH)**	**Soil type**	**Soil colour**	**Soil temperature (°C)**	**Soil moisture (%)**	**Soil pH**	**Soil salinity (ppt)**
Kelani River, Kirielamulla, Gampaha district, Western province	12.8	38	53	578	4	Muddy	Dark reddish brown	32.5	48.19	4.2	0.00
Kelani River, Kaduwela, Colombo district, Western province	22.9	38	53	578	0	Rocks	-	-	-	-	-
Biyagama, Gampaha district, Western province	19	-	-	-	-	Muddy	-	-	-	-	-
National Museum, Colombo district, Western province	16	31	70	52	1	Sandy	Light brown	31.5	0.274	5.1	0.00
Angoda, Colombo district, Western province	3.66	30.6	71	50	0	Muddy	Dark yellowish brown	31.5	10.24	7.6	0.00
Thummodara, Colombo district, Western province	16	33	65	262	0	Sandy	Yellow	31	-	6.2	0.00
Handapangoda, Kalutara district, Western province	23	32	65	126	0	Sandy	Dark yellowish brown	27	17.96	6.0	0.00
Bopath Ella, Ratnapura district, Sabaragamuwa province	16.46	34	65	105	0	Sandy	Dark yellowish brown	31.5	3.83	6.1	0.00
Katukurunda, Kalutara district, Western province	9.75	36	62	132	4	Sandy	Black	35	3.5	7.5	0.00
Aluthgama, Kalutara district, Western province	9.14	38	58	198	2	Sandy	Light yellowish brown	35	1.55	8.0	0.00

Table 2 contd...

Location	Elevation (m)	Air temperature (°C)	Relative humidity (%)	Solar radiation (w/m^2)	Wind speed (MPH)	Soil type	Soil colour	Soil temperature (°C)	Soil moisture (%)	Soil pH	Soil salinity (ppt)
Induruwa, Galle district, Southern province	8	41	45	459	8	Sandy	Reddish yellow	34	0.677	7.5	0.10
Morampitigoda, Galle district, Southern province	0.0	34	57	438	9	Sandy	Pink	34	1.40	7.4	0.10
Habaraduwa, Galle district, Southern province	0.0	33	65	1017	3	Sandy	Very pale brown	-	10.23	8.2	0.20
Matara, Matara district, Southern province	0.9	31	77	734	0	Sandy	Brownish yellow	-	8.16	8.0	0.10
Ridiyagama Wewa, Ambalantota, Hambantota district, Southern province	2.74	33	66	105	8	Sand and mud	Dark reddish brown	30	7.93	7.0	0.00
Hambantota, Hambantota district, Southern province	1.00	33	64	260	19	Sand and mud	Light olive brown	30.5	10.71	7.0	0.20
Kirinda, Hambantota district, Southern province	3.02	36	70	402	0	Sandy	Yellowish brown	39	0.20	7.0	0.00

the genera *Hypaetha*, *Lophyra*, *Calomera* and *Myriochila* were medium in size (Table 1).

Habitat parameters of locations

The eleven habitat parameters estimated for the thirty-seven locations are given in Table 2.

Artificial neural networks

In multi-layer perceptron 147 neural networks were built, trained and evaluated. The best network with the lowest mean square error and lowest misclassification rate obtained from the confusion matrix was selected as the optimum network. The network considering all the input parameters as the input space with one hidden layer, fifteen hidden neurons and tansig transfer function was chosen as the optimum network for prediction (Fig. 2). The ROC curve plotted for the network revealed that the area under the curve was >80% (Fig. 3). Therefore, the probability of correctly identifying the habitat type of tiger beetles using the above network can be interpreted as an excellent discrimination (Hosmer & Lemeshow 2000).Accuracy, precision, sensitivity and specificity of the network were highest for reservoir and urban habitat types.

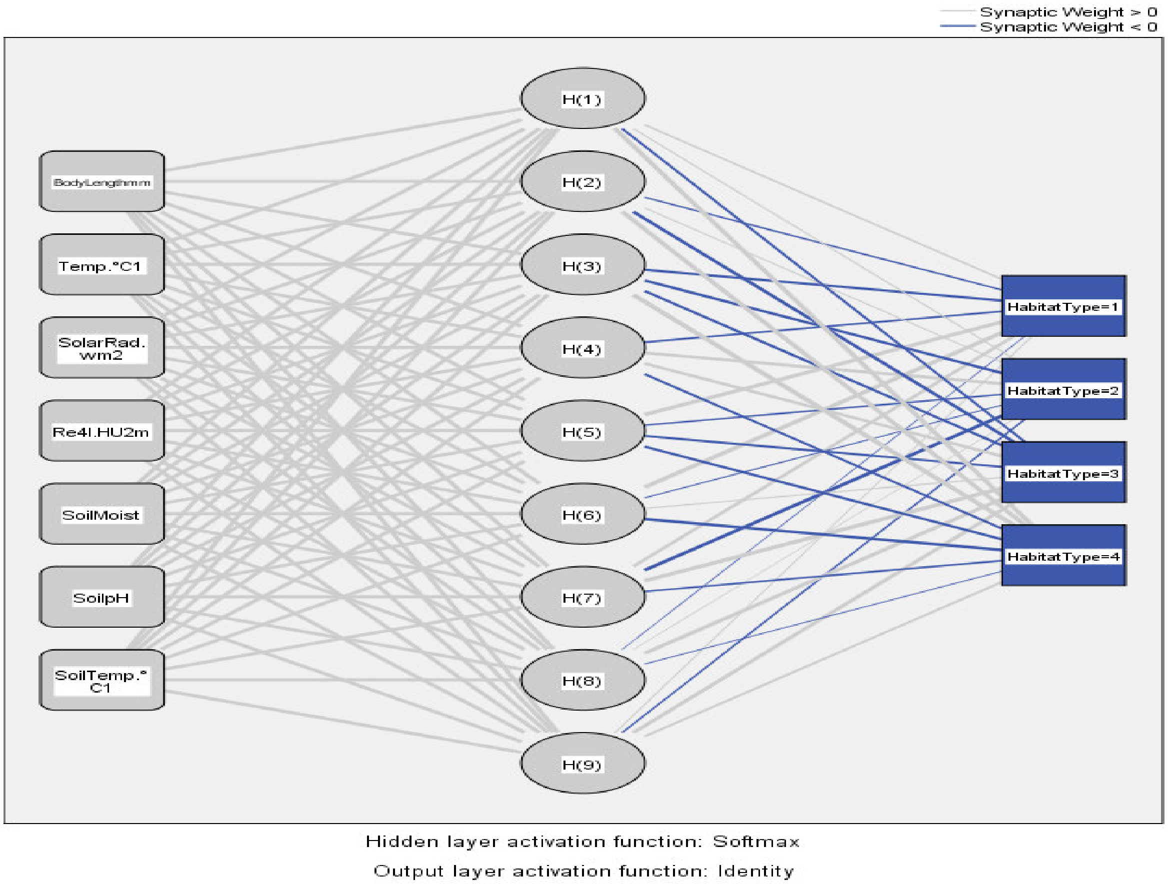

Fig. 4. Optimum network obtained by radial basis function approximation method.

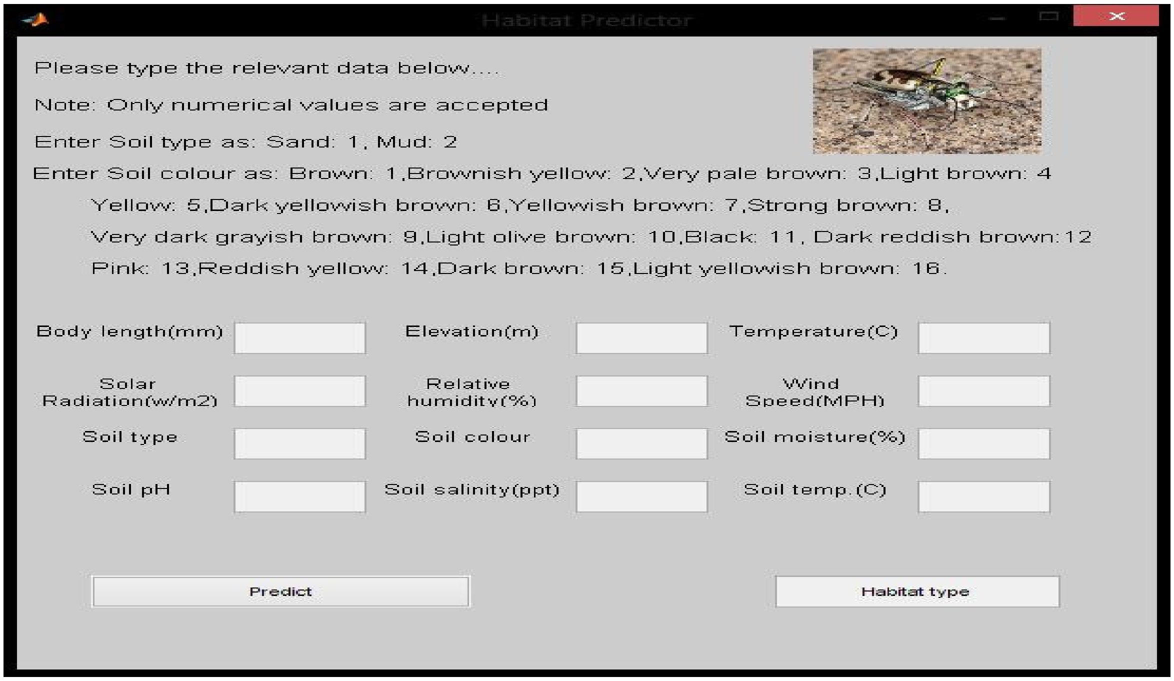

Fig. 5. Graphical user interface of the predicting tool.

In radial basis function approximation five networks with highest accuracy levels were selected for further examination. The network considering seven input variables – body length, air temperature, relative humidity, solar radiation, soil temperature, soil moisture, soil pH, with one hidden layer and nine hidden neurons was selected as the optimal network (Fig. 4). The ROC curve for the network revealed an AUC > 0.9, and identified the network as an outstanding discrimination for predicting the habitat type of tiger beetles. Accuracy, precision, sensitivity and specificity of the network were highest for reservoir and urban habitat types.

Predicting tool

A graphical user interface tool for predicting the habitat type of tiger beetles was developed (Fig. 5). The tool is able to predict habitat type by providing a minimum of seven classifiers including body length and relative humidity.

DISCUSSION

The present study reveals an association between body size and habitat type of tiger beetles which is highly significant for reservoir and urban habitats and evident in coastal and riverine habitat types. The association is dependent on the habitat parameters of the locations and the network obtained by the multi-layer perceptron method indicates that the association is dependent on all habitat parameters, while the network obtained by radial basis function approximation method reveals that the association depends on seven habitat parameters, relative humidity being most significant. The study reveals a non-linear relationship between body size and habitat parameters indicating optimal habitat conditions for large and small body sizes. By considering the body length and habitat parameters as classifiers a software tool is developed for predicting habitat type of tiger beetles.

Fifty-nine species of tiger beetles are known from Sri Lanka of which thirty-nine species are endemic (Dangalle *et al.* 2012b). Habitat types of most species are unknown and habitat parameters have not been reported for any species. However, the body sizes of species are indicated and the majority of endemic species represented by genera *Jansenia* and *Cylindera* are known to be small. Recent investigations conducted from 2003 to 2014 in 107 locations of Sri Lanka have revealed three species from genus *Cylindera* from riverine habitats of the wet zone of the country (Dangalle *et al.* 2011a, b). However, nine species from genus *Cylindera* have been reported from the country. Further, all species of genus *Jansenia* were not discovered, despite extensive investigations throughout all climatic zones and different habitat types. Absence of these species and lack of information of their locations and habitats renders them vulnerable to future extinction. The insects of Sri Lanka is a highly neglected faunal group in the country, and rarely included in biodiversity databases (Wijesekara & Wijesinghe 2003). They are not included in the conservation strategies implemented for conservation of flora and fauna of the country and most species may already be extinct. The present study associates body size of tiger beetles with habitat type and habitat conditions and provide a software tool to predict habitat type of tiger beetles. The tool will limit extensive investigation and reduce loss of time and expenses that is critical for a developing country such as Sri Lanka. Further, we intend to conduct studies which will consider prey choice, predators and vegetation types and cover that will more accuracy and stability to the current study.

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