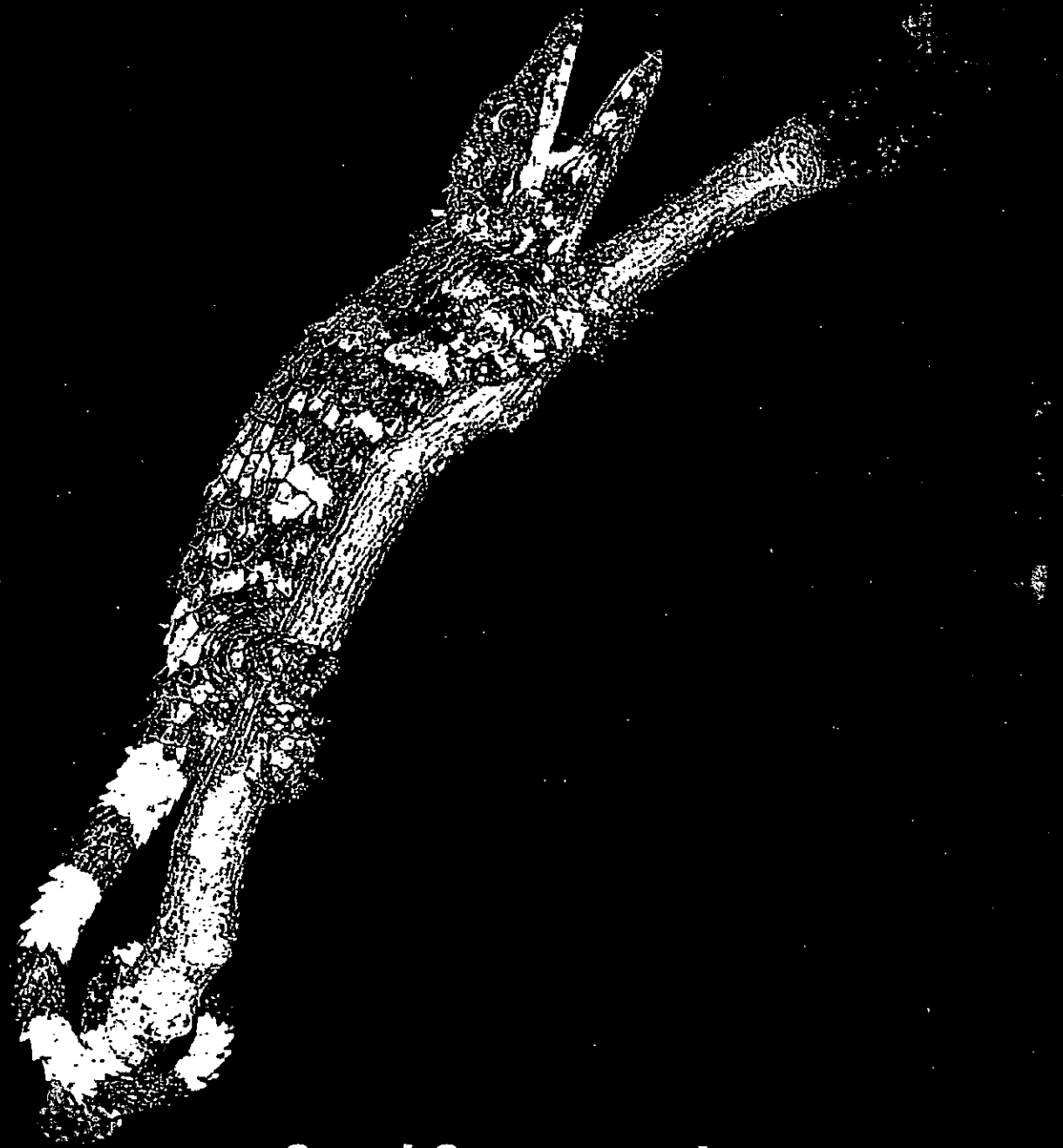
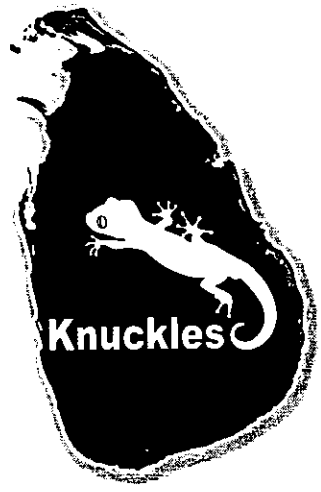
The Herpetofauna Of the Knuckles Range



Suraj Goonewardene
John Drake
Anslem de Silva

2006



The Herpetofauna of the Knuckles Range

Suraj Goonewardene [1], John Drake [2] and Anslem de Silva [3]

[1]97, Battersea Park Road, London, SW9 4DU. E-mail: **hsr.wild@gmail.com**
[2]Creagard, Isle of Mull, PA75 6RA, UK. E-mail: **jfdrake@gmail.com**
[3]15/1 Dolosbage Road, Gampola, Sri Lanka. E-mail: **kalds@sltnet.lk**

Project Website: www.hoona.co.uk

Project Knuckles 2004-5, University of Edinburgh Research Expedition

2006

The Herpetofauna of the Knuckles Range

Copyright: © Suraj Goonewardene, John Drake and Anslem de Silva

Citation: Goonewardene, S., J. Drake and A. de Silva. 2006. The herpetofauna of the Knuckles range. Project Knuckles 2004 & 2005: University of Edinburgh Research Expedition. Amphibia and Reptile Research Organization of Sri Lanka (ARROS) Pages 1 to ..... and 13 to 206.

Front Cover: *Cophotis ceylanica*[1]
Back Cover (Left to right): *Ceratophora tennentii*[1], *Calotes liocephalus*[1], *Chalcidoseps thwaitesii*[1], *Cyrtodactylus soba*[2], *Hypnale hypnale*[1], *Liopeltis calamaria*[1], *Lygosoma singha*[1], *Dasia halianus*[1], *Geckoella triedrus*[1], *Nannophrys marmorata*[1],
Photographs ©: S. Goonewardene[1] and L. Packham[2]

Photographs of Plates R1 to R17 ©: Suraj Goonewardene, Anslem de Silva, G. Chandrawansa, L. Packham and A. Ford

Photographs of Plates 1 to 14 ©: Suraj Goonewardene, Anslem de Silva, J. Drake, S. Wilson, R. Meek, G. Chandrawansa, L. Packham and A. Ford

Cover design & sketches (*Ceratophora tennentii, Lyriocephalus scutatus and Cophotis ceylanica*) : A. Mike Fernando ©: University of Edinburgh Research Expedition. Amphibia and Reptile Research Organization of Sri Lanka (ARROS)

Project Knuckles 2004-5, University of Edinburgh Research Expedition
in collaboration with
The University of Edinburgh
Amphibia and Reptile Research Organization of Sri Lanka (ARROS)
Declining Amphibian Populations Task Force (DAPTF)
IUCN/SSC, Working Group, Sri Lanka

Printed May 2006

H.S.R. Goonewardene,
97, Battersea Park Road,
London SW8 4DU.

07810116672
02074987189

19/07/2006.

Dear Sir/ Madam,

Re. Project Knuckles 2004 & 2005 - University of Edinburgh Expedition.

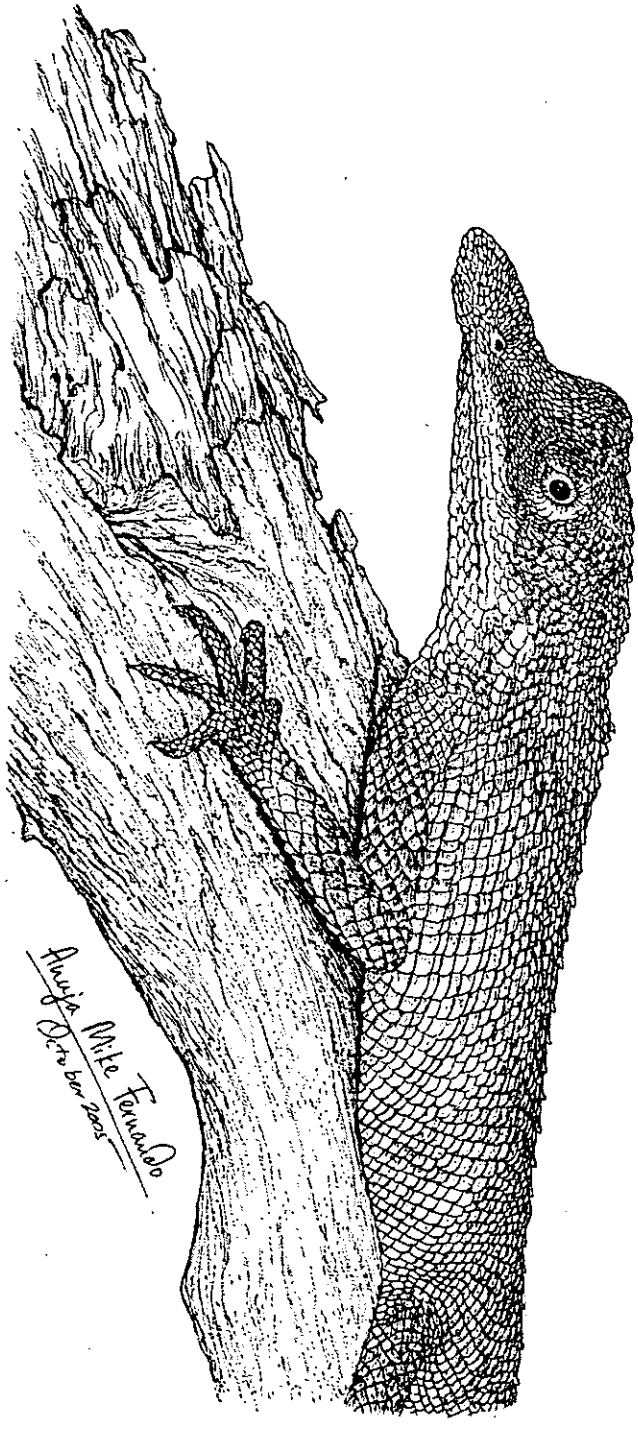
I enclose the report of the above expedition, which has now been concluded. I would like to thank you on behalf of the research team and all our collaboraters, because without your support this project would have not been possible.

The research has contributed towards the the Knuckles Mountain Range status being upgraded shortly to a World Heritage Site.

Yours sincerely,

Suraj Goonewardene
Expedition Leader
Project Knuckles 2004 & 2005

Frontispiece
Sketch of *Ceratophora tennentii*



List of contents

Page

SECTION 1.
REPORT OF THE KNUCKLES EXPEDITION,2004 AND 2005.....01-165

Sketch of *Cophotis ceylanica*.....03

Editorial Note.....11

Executive summary.....12

List of participants.....13

Acknowledgements.....15

Chapter 1 – Introduction.....17

Chapter 2 – Methodology.....25

Chapter 3 – Agamids.....35

Chapter 4 – Skinks.....61

Chapter 5 – Geckos.....71

Chapter 6 – Snakes.....85

Chapter 7 – Crocodiles, turtles and monitor lizards.....107

Chapter 8 – Amphibians.....113

Chapter 9 – Other vertebrates and invertebrates.....119

Chapter 10 – Threats, conservation and recommendations.....123

Literature cited.....139

Annexure 1 – Canopy investigations.....155

Annexure 2 – Archaeological findings.....161

Annexure 3 – Summary table of Visual Encounter Studies.....163

SECTION 2.
PUBLICATIONS ENSUING FROM KNUCKLES EXPEDITION – 2004 AND 2005

(Published in *Lyriocephalus* Vol. 6 (1 & 2). ISSN 1391-0833
13 to 206 (original page numbering in the journal).

1. The Diversity of the Knuckles Ecosystem, with special reference to its Herpetofauna. de Silva, A., A. M. Bauer, C. Austin, S. Goonewardene, J. Drake, P. de Silva, M.G.T.H. Aberathna, T. Dassanayaka, G. S. Samarawickrama, R.D.C.S.K. Dasanayaka, A.M.R.K. Amarakoon & M. M. Goonasekera (2005a).

2. Species diversity and richness of the Herpetofauna in large leaf litter plots in the Knuckles Ecosystem.
de Silva, A., S. Goonewardene, J. Drake, P. de Silva, R.D.C.S.K.Dasanayaka, A. M. R. K. Amarakoon & M. M. Goonasekera. (2005b).

3. Status of the Agamids in the Knuckles massif with special reference to *Calotes liocephalus* (Gunther, 1872) and *Cophotis ceylanica* (Peters, 1861).
de Silva, A., A. M. Bauer, S. Goonewardene, J. Drake, S. Nathanael, W.P.R.Chandraratne, and S.A.U.S. Somathilaka. (2005c).

4. *Ceratophora tennentii* (Gunther and Gray, in Tennent, 1861) (Reptilia: Agamidae), Some notes on its ecology.
de Silva, A., A. Bauer, S. Goonewardene & J. Drake. (2005d).

5. First studies on thermal ecology of *Ceratophora tennentii* (Reptilia: Agamidae) inhabiting the Cloud forests of the Knuckles Massif, Sri Lanka.
de Silva, A., R. Meek, A. Bauer, S. Goonewardene, J. Drake, R.D.C.S.K. Dasanayaka, A.M.R.K. Amarakoon & M. M. Goonasekera. (2005e).

6. Preliminary investigation on the parasites of Agamids inhabiting the Knuckles mountain range, with special reference to *Ceratophora tennentii* (Reptilia: Agamidae).
de Silva, A., R. P. V. J. Rajapaksa, R.R.M.K.K. Wijesundera, A. Bauer, S.Goonewardene, J. Drake, M. de Silva and N. A. N. D. Perera. (2005f).

7. Insect attacking an *Otocryptis wiegmanni* (Reptilia: Agamidae).
de Silva, A. and S. Goonewardene. (2005g).

8. Altitudinal differences in thermoregulatory behaviour in *Calotes versicolor* in the Knuckles region, Sri Lanka.
Meek, R., E. Jolley, de Silva, A., S. Goonewardene, J. Drake, H.M.N. Chalalochani, P.L.C.L.Liyanage, T.S. Abeysekera, M.D.I.P.K.Mayadunna, S.A.U.S. Somathilaka, W.P.R. Chandrarathna. 2005.

9. Observations on the Skinks inhabiting the the Knuckles massif: with special reference to the genus *Lankascincus*.
de Silva, A., C. C. Austin, A. M. Bauer, S. Goonewardene, J. Drake, P. de Silva, T. Shripathy, S. Ramesh, K. Suthagar & A. Kajatheepan. (2005h).

10. *Chalcidoseps thwaitesii* (Gunther, 1872) (Reptilia: Scincidae) Four-Toed Skink: Preliminary observations.
de Silva, A., A. M. Bauer, C. Austin, S. Goonewardene, J. Drake & P. de Silva. (2005i).

11. Notes on *Nessia* species inhabiting the Knuckles massif with special reference to *Nessia bipes* (Smith, 1935) (Reptilia: Scincidae) : the dominant snake skink.
de Silva, A., A. Bauer, C. Austin, S. Goonewardene, J. Drake, A. Balasubramaniam, C. Rajendran, V. Pathmadevan, M. Fernando & K.Sureshkumar. (2005j).

12. Some observations on the geckos inhabiting the Knuckles massif.
de Silva, A., A. M. Bauer, S. Goonewardene, J. Drake, S. Nathaniel & P.de Silva. (2005k).

13. The Dumbara Bent-toed Gecko (*Cyrtodactylus soba*) the dominant gekkonid lizard inhabiting the Knuckles massif.
de Silva, A., A. Bauer, S. Goonewardene, J. Drake & P. de Silva. (2005l).

14. Observations of gecko cannibalism.
de Silva, A., S. Goonewardene, J. Drake, & A. Bauer. (2005m).

15. Notes on the Snakes inhabiting the Knuckles massif with special reference to *Uropeltis melanogaster* (Gray, 1858) and *Uropeltis phillipsi* (Nicholls, 1929).
de Silva, A., S. Goonewardene, A. Bauer, C. Austin, J. Drake & P. de Silva. 2005n.

16. The amphibian diversity in the Knuckles massif with special reference to relict species.
de Silva, A., S. Goonewardene, J. Drake, & P. de Silva. (2005o).

17. Preliminary observations on some parasites of geckos, skinks and snakes inhabiting the Knuckles massif.
de Silva, A., R. P. V. J. Rajapaksa, R.R.M.K.K. Wijesundera, M. de Silva, A. Bauer, S.Goonewardene, J. Drake, C.C. Austin, N. A. N. D. Perera, D. de Silva, U. Hemachandra , C. Nelawatura & D. A. Sathrasinghe. (2005p).

18. Some observations on the molluscs of the Knuckles massif.
de Silva, A., K. B. Ranawana & S.Goonewardene. (2005q).

19. Evidence of Prehistoric cave dwellers inhabiting the Knuckles massif: Preliminary archaeological findings.
de Silva, A., R. M. M. Chandraratne, S. Goonewardene, J.A.D.M.M. Jayasuriya, D. Ellepola, & P.B.N. Abeywardana. (2005r).

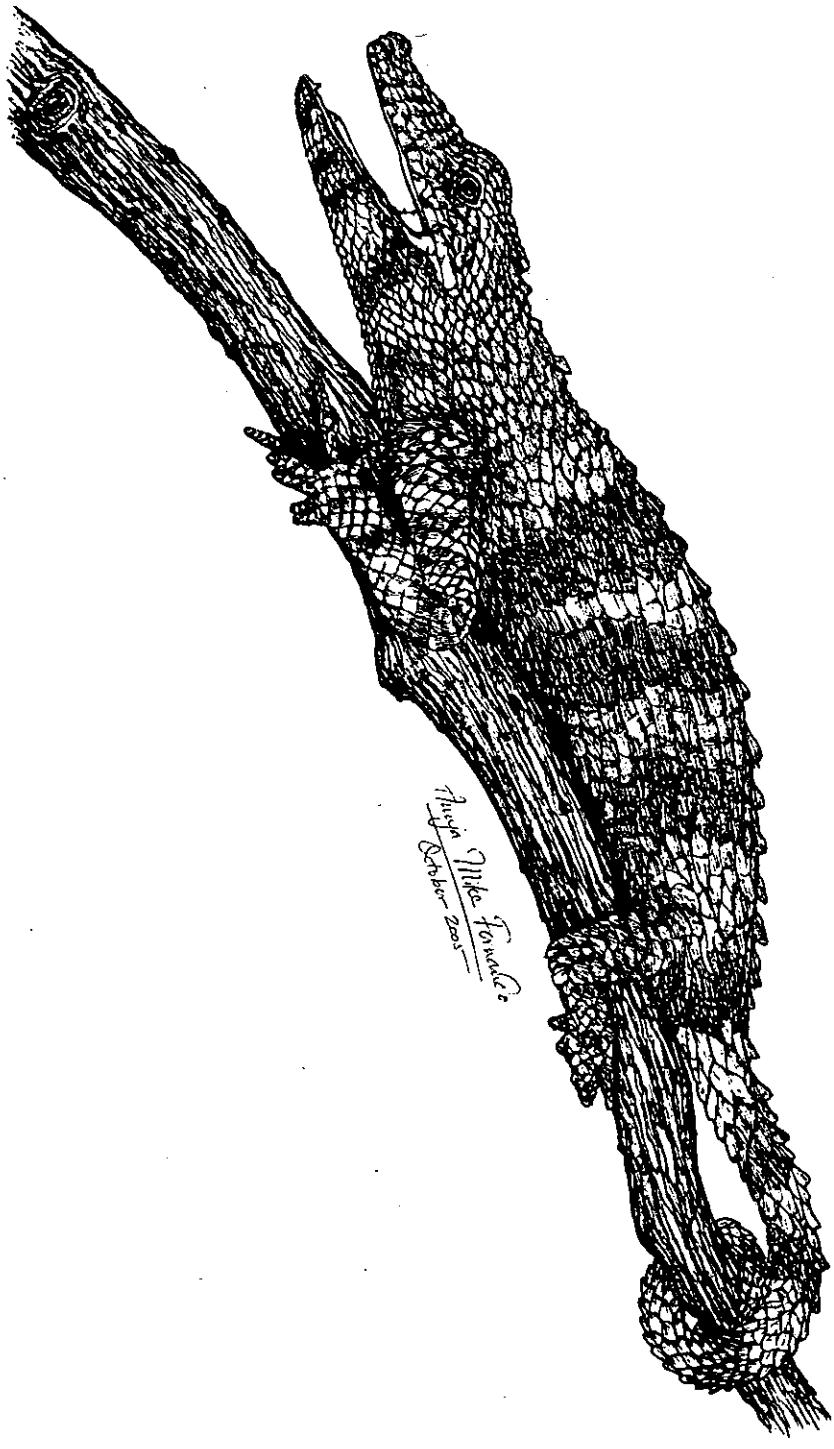
20. A possible burial site with rock carvings from the Knuckles massif.
de Silva, A., S. Goonewardene & R. M. M. Chandraratne. (2005s).

21. Some archaeological monuments and traditions of the North East Knuckles.
de Silva, A., R. M. M. Chandraratne, S. Goonewardene, J. Drake, J.A.D.M.M. Jayasuriya, H.M.N.W. Herath, P.B.N. Abeywardana & W. M. R. P. K. Chandradasa. (2005t).

22. Some cultural traits and attitudes of the inhabitants of Mimure (in the Knuckles massif) towards local animals with special reference to herpetofauna.
de Silva, A., A. Bauer, S. Goonewardene, J. Drake, G. S. Samarawickrama & M. M. Goonasekera. (2005u).

REPORT OF THE KNUCKLES EXPEDITION,2004 AND 2005

Sketch of *Cophotis ceylanica*



Editorial Note

The present publication: *Herpetofauna of the Knuckles Range* consists of two sections:

Section 1 - deals with the Knuckles expedition report and findings of projects Knuckles 2004 and 2005. 18 colour plates in this section are referred as Plate R1 to R18.

Section 2 - deals with papers ensuing from projects Knuckles 2004 and 2005 which were published in *Lyriocephalus*, (volume 6 numbers 1 & 2), the journal of Amphibia and Reptile Research Organization of Sri Lanka. 13 colour plates in this section are referred as Plate 1 to 13.

Please note that for the purposes of making it easier to read, references in Section 2 by author De Silva, A. have been listed 2005a,b, c, etc. (see bold) in the order that they were published in the Journal. They are subsequently referenced in the text as "De Silva *et al.*, 2005a and so on.

Several more papers are in preparation to be published in other international journals. Already one paper "The ecology and distribution of *Geckoella triedrus* in the Knuckles" and "The ecology and distribution of *Cyrtodactylus soba*: in the Knuckles massif" are to be published in ***Gekko***, the journal of the Global Gecko Association.

The papers in Section 2 were edited by an editorial board comprising Anslem de Silva, Professor Indraneil Das, Malik Fernando, S. Nathanael and were also reviewed by Professor Aaron M Bauer, Christopher C. Austin and Edie Jolley.

Also note there was considerable variation in spelling of locations/study sites in the Knuckles area in available literature and for the purposes of this report, have used the names printed in the latest available Ordinance Survey maps of the region.

Suraj Goonewardene, John Drake & Anslem de Silva.
May 2006

Executive summary

Project Knuckles was the first in-depth herpetofaunal study of the Knuckles Mountain Range to investigate and assess the status of the amphibians, reptiles and their habitats in the Knuckles Mountain Range, Sri Lanka. Spanning two years, the University of Edinburgh Research Expedition commenced work in July 2004 with the assistance of Sri Lankan herpetological expert Anslem de Silva, President of the Amphibian and Reptile Research Organisation of Sri Lanka (ARROS). The main aim of the expedition was to provide information for the formulation of up-to-date conservation status reports of the globally threatened reptile species which inhabit the Knuckles range. Working in conjunction with the Sri Lankan Universities of Rajarata, Peradeniya, Jaffna, Sri Jayawardenapura and Batticaloa (Eastern University of Sri Lanka), the project has trained 35 undergraduate students in the latest herpetological techniques and it is hoped that they will continue with the research in time to come.

The study indicates that the Knuckles range harbours a higher diversity of reptiles and amphibians than previously known. The project has documented the presence of 76 species (of which 41% are endemic) of reptile inhabiting the Knuckles range. These findings surpass last survey carried out in 2003 by the IUCN by an additional 23 species. Furthermore to date 5 - 10 additional specimens which cannot be identified using available keys. This suggests that these species may be new to science, which will be confirmed with molecular and alpha taxonomical investigation, currently underway. The information gathered during the project will be used for current taxonomical revisions by Anslem de Silva in collaboration with Professor Aaron Bauer (University of Villanova, on the Geckoes of Sri Lanka) and Dr. Christopher Austin (Museum of Natural Science, Louisiana State University, on the Skinks of Sri Lanka).

In order to reassess the status of all of the above species, the project had to perform the first in depth study of their natural history, which included observations on their microhabitat, diet, parasites, territoriality, predators, reproduction, colour variations, thermoregulation activites, sympatric fauna, habitat associations and distribution. The project has documented various anthropological activities which are threatening the ecosystems and species of the Knuckles range. To try to counteract this, the project has carried out conservation education activities amongst the residents of the Knuckles range.

To date 22 research papers have been written and co-authored by the team, Anslem de Silva and numerous experts around the world. These papers were published in the journal *Lyriocephalus* (the only indexed herpetological journal of Sri Lanka) special edition, entitled *'The Diversity of the Dumbara Mountains (The Knuckles Massif, Sri Lanka): With special reference to its herpetofauna. Lyriocephalus, 2005 November, Volume 6 Numbers 1 & 2.*

The project is hoped to be a model where future conservation research can be carried out with collaboration with foreign universities and Sri Lankan counterparts, as one of the main constraints limiting such research being lack of funding and exposure. The challenge now is to use the results of Project Knuckles to improve the conservation prospects of the Knuckles.

List of University students and other personnel who participated in the Project Knuckles 2004 and 2005

PROJECT KNUCKLES 2004 STUDENTS

University of Edinburgh, United Kingdom
Alasdair Ford,
Andrew J.G Burns,
Douglas Fraser.
John Drake,
Laura Packham,
Polly Bramham,
Suraj Goonewardene

University of Peradeniya (Archaeology students)
H.M. Ganga Sajeewani Samarawickrama

University of Sri Jayewardenepura
D.M.Tharanga Dassanayaka
M.G. Theja Hemamali Aberathna

Rajarata University of Sri Lanka
A.M.R.K. Amarakoon
R.D.C.S.K.Dasanayaka

Amphibia and Reptile Research Organization of Sri Lanka (ARROS)
Panduka de Silva
Vajira Gajamergedara

PROJECT KNUCKLES 2005 STUDENTS

University of Edinburgh, United Kingdom
John Drake
Suraj Goonewardene

Eastern University of Sri Lanka, Chenkalidai, Batticaloa
Jesuthasan Mathews Fernando
Kandasamy Sureshkumar
Kunaseelan Suthagar
Ramalingam Sivapathis
Shanmugam Kirupakaran

University of Jaffna
Abeyrami Balasubramaniam
Arunasalam Kajatheepan
Chanthirica Rajendran
Manivathani Subramaniam
Varoopah.Pathmadevan

University of Peradeniya (Archaeology students)
Deepanjalee Ellepola
Don Chethani Jayasinghe
Jayasuriya Arachchige Dona Mubhashini Menaka Jayasuriya
Peruma Baduge Nuwan Abeywardana
Uditha Niroshini Jinadasa
Wasala Mudalige Ruchirangana Prabath Kumara Chandradasa

University of Peradeniya (Veterinary students)
Chandana Nelawatura
Dilshan de Silva
Manjula Jayasinghe
Umasha Hemachandra

University of Sri Jayewardenepura
Krushantha Bandara Ekanayake
R. M. C. S. Kumari
Samiddhi Darshana Wijethilaka
Umanga Chalani Dissanayaka

Rajarata University of Sri Lanka
H. M. Nadeesha Chalalochani
Mayadunnage Don Irosha Piyadarshi Kumari
Palpola Liyanage Chamali Lasanthi Liyanage
Somarasundara Arachchige Udaya Sampath Somathilaka
Tharaka Sampathi Abeysekera
Witharamalage Palitha Rathnakumara Chandrarathna

Amphibia and Reptile Research Organization of Sri Lanka (ARROS)
Panduka de Silva
Vajira Gajamergedara

Resource Personnel
Anslem de Silva, Sri Lanka
Edie Jolly, United Kingdom
Roger Meek, United Kingdom

Acknowledgements

We thank the Edinburgh University Courts and the University Expeditions Panel for their approval and support which allowed us to conduct the Knuckles expeditions of 2004 and 2005.

The following institutions provided funding:

The Aranmore Memorial Travelling Scholarship (University of Edinburgh) - 2004

The British Student Travel Fund - 2004

The BP Conservation Award (Silver) - 2005

The Carnegie Award - 2004

The Davis Fund (University of Edinburgh) - 2004 & 2005

The Edinburgh University Number Two Fund - 2004

The Gilchrist Educational Trust - 2004

The Global Gecko Association - 2004 & 2005

The Global Canopy Programme - 2004 & 2005

The James Rennie Bequest (University of Edinburgh) - 2004 & 2005

The Lindeth Charitable Trust - 2004
The People's Trust for Endangered Species - 2004 & 2005

The Royal Geographical Society Expedition Research Grant - 2005 & Gumby Award 2004The Student Travel Fund (incorporating the Norman K. Smith Memorial Fund) (University of Edinburgh) - 2004 & 2005

The Weir Fund (University of Edinburgh) - 2004 & 2005

The William Dickson Travelling Fund (University of Edinburgh) - 2004

Wilderness Medicine Training Bursary - 2004

We thank the following personnel and institutions for their approvals and support:

The Director General of the Department of Wildlife Conservation for granting permission to conduct the project (WL/3/2/1/14/12).

Mr. M P A U Sarath Fernando, Conservator General of the Forest, and Mr. K. P. Ariyadasa, Conservator of Forests (Operations), for granting permission (reference FRC/7 dated 29.4.2004, reference FRC/7 dated 29.4.2005) to conduct the project.

The District Forest Officers at Kandy and Matale and the Forest Department officers at Loolwatte - Mr. Wattegama and Illukkumbura . Priyantha Brahammana.

Dr Nick Hulton, Dr. Kate Heal and Mrs Margaret Jackson of the University of Edinburgh's Expedition Approval Committee for all their support and patience from start to finish.

Dr. Manel Goonesekera, Dean, Faculty of Applied Sciences, Rajarata University of Sri Lanka, Mihintale, and her herpetology students for their participation.

Dr Shirani Nathanael, Rajarata University of Sri Lanka, Mihintale, for editing this report.

Dr. R. P. V. J. Rajapaksa, Faculty of Veterinary Science, University of Peradeniya for parasitological investigations.

The Commissioner of Archaeology, and Mr. M. B. Herath, Director (Common Services),

Archaeological Department, Colombo, Sri Lanka.

Taxonomical experts consulted - Professor Aaron Bauer (University of Villanova), Dr. Christopher Austin (University of North Dakota), Dr. Idraneil Das (University of Malaysia Sarawak) and Kelum Manamendra-Arachchi (Wildlife Heritage Trust, Sri Lanka).

Dana C. Savorelli, of Midwest Tongs.com Company, USA for donating herpetological equipment to Anslem de Silva and students of the Rajarata University of Sri Lanka, Mihintale.

Exped (Expeditions Society of the University of Edinburgh), particularly to former President Alex Phythian-Adams, for his helpful tips.Derek Scott of BTO labs for providing equipment to carry out work in the field.John Pike, Andy Barrell, Andrew Mitchell and James Aldred of the Global Canopy Programme for training and for an equipment grant.

Anjula Mike Fernando for his line sketches to enhance the quality of the report.

Our families, Mrs. Mariska Mendis and Mrs. Jennifer de Silva for their encouragement.

The proprietors of Corbett's View and Eagles Crest, Loolwatte, Knuckles and Ibis Lodge, Wilgamuwa, Hettipola for providing lodgings during the Knuckles project.

Our drivers Sunil, Anurudha and Fernando, the residents of Hunnasgiriya, Loolwatte and Namini Oya, especially Bandara, Johann, Sirisena, his wife Kusuma and a host of other guides and volunteers throughout the region, who assisted us during this project.

Chapter 1
Introduction

The wet zone of Sri Lanka and the Western Ghats of India are together considered to be one of the eight "Hottest hotspots" of biodiversity in the world (Myers 2000). This indicates that these areas have both one of the highest levels of biodiversity in the world, and that this biodiversity is highly threatened.

Crusz (1984) considers that the forests of the Wet Zone of Sri Lanka contain the most distinctive and conservative elements of Sri Lanka's reptilian fauna - they have been least influenced by relatively recent invasions from the Indian mainland.

Austin *et al* (2004) have shown that a diverse and highly endemic herpetofaunal assemblage has developed despite Sri Lanka's close proximity to the mainland. Molecular DNA sequence approaches of *Lankascincus*, a scincid genus endemic to the island of Sri Lanka, have also shown an independent lineage separate from the *Eugongylus-*, *Mabuya-*, *Egernia-*, or *Sphenomorphus-* groups.

Furthermore, recent studies using molecular phylogenies have shown that Sri Lanka has maintained a faunal diversity quite distinct from that of the Indian Western Ghats (Bossuyt *et al.*, 2004, Meegaskumbura *et al.*, 2002, 2005).

Species diversity of Wet Zone herpetofauna is rich, with high levels of endemism and a number of geographical relict animals. Presently, Sri Lanka has one of the highest levels of amphibian diversity per unit area of land in the world (3.9 per 1,000 km^2) (Pethiyagoda and Manamendra-Arachchi 1998; Manamendra-Arachchi & Pethiyagoda 2005; Meegaskumbura and Manamendra-Arachchi, 2005). Certain forests of the Wet Zone have been protected for millennia by the Sri Lankan monarchy (de Silva, 1980; 1990). However, as indicated by its "Hottest hotspot" nomination, Sri Lankan biota is today facing considerable threats; and this is mainly due to anthropogenic activity. The biggest impact upon biodiversity to date is the clearance of major portions of Wet Zone natural vegetation (including areas of the Knuckles Massif), which commenced during the first half of the 19th century, initially for coffee cultivation (*Coffea arabica*). However, with the advent and rapid proliferation of 'coffee rust' disease (*Hemeleia vastatrix*) in 1867, the island's plantations were decimated and the recently established Chinese crop, tea (*Camelia sinensis*) replaced coffee. The latter was cultivated on a much larger scale. Even in the Knuckles, montane forests were cleared to within a "few hundred feet of the crest" (Cooray 1961). Recently, with developing improvement in the country's health care system, the Sri Lankan human population has increased considerably. Cincotta *et al.*, (2000) indicate that the population density of Sri Lanka and the Western Ghats is in fact the highest of the global hotspot regions. The population density in the biodiverse Wet Zone quarter of the country is 700 per km^2 (Anon, 2003).

Fourteen percent (14%) of Sri Lanka is protected forest or scrubland (Wijesinghe, 2000). However, most of this area lies in the less biodiverse Dry Zone. Despite housing extremely high levels of biodiversity, the protected areas left in the Wet Zone are few, under developed and face various threats, most of which are dismissed and little publicized. These threats are largely due to anthropogenic activities, whereby instigators are ill-informed of the importance of biodiversity and how their activities are harming it. Even when they are aware of the environmental disruption caused by their activity, due to poverty they are left with few alternatives. Threats and conservation issues are discussed in detail (Chapter 10). Further resources and funding must be provided to organisations capable of protecting the remaining areas of biodiversity, whilst citizens living in and around areas of high biodiversity must be integrated with their natural surroundings through conservation education, which

demonstrates the importance of their local natural ecosystems. If steps are not taken to protect the few remaining natural forests of the Wet Zone, they will be lost, taking high levels of biodiversity with them.

The Knuckles Mountain Range

Divided between the Wet Zone and the Dry Zone, the Knuckles Massif lies north east of Sri Lanka's second largest city of Kandy (Figure 1). It takes its name from a series of recumbent folds and peaks in the west of the massif, which, when viewed from certain locations in the Kandy district, resemble the knuckles of a clenched fist. Whilst early British surveyors assigned this name, the Sinhalese have traditionally referred to the area as the Dumbara Kanduvetiya or mist-laden mountain range (Cooray, 1984). The entire area is characterised by its striking peaks and vistas often robed in thick layers of cloud. In addition to Its aesthetic value, the range is of great scientific interest. The conditions of all Sri Lanka's climatic zones are exhibited in the Knuckles massif and is a climatic microcosm of the rest of the country. At higher elevations, there are a series of isolated Cloud Forests, harbouring a variety of flora and fauna, some of which cannot be found anywhere else in the world. Although the range constitutes approximately 0.03% of the island's total area, it is home to a large proportion of the country's biodiversity (Table 1).

Unfortunately, the importance of this mountain range is being ignored. Human activity continue to damage and degrade the fragile ecosystems, threatening the fauna and flora and the survival of certain key endemic species. Much of the original pristine forest area of the Knuckles Mountains was cleared during the nineteenth century for the cultivation of coffee (*Coffea arabica*) followed by the widespread cultivation of tea (*Camelia sinensis*) and soil degradation has followed. Some areas are still cultivated for vegetable crops using traditional slash and burn techniques. Despite being declared a forest reserve in 1873, areas lying above 1500m (5000 ft) contour were utilised for the cultivation of cardamom (*Elletaria cardamomum*). During the 1960s this cardamom cultivation expanded considerably and the Knuckles grew to become the country's highest cardamom producing area. Cardamom cultivation requires well-forested areas at high elevations with good rainfall, soil and drainage. Suitable areas on the mountains are then cleared of their lower levels of vegetation. The trees are thinned, but some are left intact to provide shade and shelter from the elements. They are then under planted with cardamom plants, which when fully grown, must have their surroundings maintained and cleared. The farmer must weed the area, removing all other competing vegetation, which prevents the regeneration of native forest plants.

Since 1975, Dotalugala, a prominent peak in the Knuckles Massif, has borne the status of 'Man and Biosphere reserve', under the remit of the Sri Lankan Forestry Department (Sri Barathi, 1979; 1988). In May 2000, this was included in the 17,500h of Knuckles conservation forest by Gazette Notification (2000). Areas above 1,067m (3,500ft) in altitude became protected. This declaration stipulates the abandonment of anthropogenic activities, including cardamom cultivation within the protected area. Proposals are currently being made to declare the area a World Heritage Site and an International Man and Biosphere Area.

Project Knuckles is a University of Edinburgh expedition, which set out to study the threatened herpetofauna of the Knuckles Range. In addition to documenting distribution patterns, it also aimed to assess the threats faced by the herpetofauna. Once analysed, the findings of the project were published and distributed amongst the wider scientific community, including the Forest and Wildlife Departments of Sri Lanka who are the official custodians and managers of the region's forests. It is hoped that by publicizing the ecological importance of the Knuckles Range, assistance for the preservation of the area will be drawn from a wider, global pool of resources and organisations.

In addition to being a University of Edinburgh expedition, Project Knuckles conducted its research with students from the Sri Lankan Universities of Jaffna, Rajarata, Peradeniya, Sri Jayawardenepura and Batticaloa (Eastern). The students involved were taught the latest herpetological field techniques and it is hoped that this will help them to lead their own herpetological research in Sri Lanka in the future. As well as improving academic links between the United Kingdom and Sri Lanka, Project Knuckles hopes to improve the field of Herpetology, both in these two countries and the wider world.

To date, the project has physically verified and documented the presence of 76 species of reptile inhabiting the Knuckles range. Of these 54 % are endemic and 14 species belonging to 8 genera are geographical relicts to the country. These findings surpass both those of Project Knuckles 2004 [Phase I] and the IUCN (Sri Lanka) survey (Bambaradeniya and Ekanayake, 2003) results by an additional 23 species. The observations of Ginige (1994) are surpassed by an additional 35 species (Table 1).

Table 1
Reptile species observed during Project Knuckles 2004 and 2005 in comparison to other surveys (number of endemics within parenthesis)

Taxonomic Group Family	**Project Knuckles 2004Number of species**	**Project Knuckles 2005 Number of species**	**Ginige, (1994)**	**IUCN Number of Species**
Crocodylidae	0	1	0	0
Bataguridae	1	1	1	1
Testudine	0	1	0	0
Trionychidae	1	1	1	1
Agamidae	9	10 (8)	8	8
Gekkonidae	8	13 (8)	5	8
Scincidae	8	14 (10)	4	6
Varanidae	2	2	2	2
Boidae	0	1	1	1
Colubridae	16	21(8)	13	16
Elapidae	1	2(1)	2	2
Typhlopidae	1	2	0	1
Uropeltidae	3	4 (4)	1	4
Viperidae	3	3 (2)	3	3
Total	**53**	**76 (41)**	**41**	**53**

Geology

During the Pleistocene period (20,000 years before present), due to a drop in sea levels (of up to 120m) a 140 km wide landmass between Sri Lanka and India emerged. These periodic land connections have occurred several times during the past 500,000 years (Rohling *et al.*, 1998). Whilst some species of plant and animal such as *Uropeltidae* (fossorial snakes) were able to migrate across these land bridges, certain species remained isolated at higher altitudes due to their inability to travel to the lowlands and cross into what is now India. A small selection of species remained high up in the Sri Lankan Highlands. The remnants and descendents of these species can still be observed today, including the Leaf-nose Lizard (*Ceratophora tennentii*), found only at the peaks of the Knuckles mountains, or the monotypic Four-toed Snake Skink (*Chalcidoseps thwaitesii*), also found only around the Knuckles Mountains (De Silva *et al.*, 2005i.). These species cannot be seen anywhere else in the world, although they have relatives in the Central and Rakwana hills of Sri Lanka.

The interior geography of Sri Lanka can be described as having three massifs, running from north to south. Of these massifs, the Knuckles are the most northerly. Geographically and geologically, it forms a part of the northern block of what is referred to as the 'Hill Country' but is separated by both the Kandy plateau and the broad Dumbara valley, both to the south of the range. Hydrologically, the Knuckles massif is crucial to the country, as it forms a major part of the Upper Mahaweli Watershed area (Giragama & Wickramaratne, 2005).

The high altitudes in the region lead to the frequent formation of thick cloud layers around the peaks, hence the origin of its local name, mist-laden mountain range. As will be outlined later, the importance of this cloud extends beyond the aesthetic. It plays a crucial role in the development of the Knuckles Mountains as a haven for biodiversity.

Elongated in shape, the Knuckles area extends much further than the signatory five peaks. The main ridge of the range is composed of the Knuckles mountain itself (1863m), Gombaniya (1904m), which is the tallest in the range, Kirigalpotta (1647m), Kobonillagala (1554m), Dotolugala (1574m), and Nawanagala (1486m). Extensions protruding from this main ridge include other notable peaks such as the instantly recognisable Lakegala (1318m), the most widely known of the mountains in the range, its triple peak and triangular escarpment face dominating the view in local villages such as Meemure, Dumbanagala (1641m), Kehelpothdoruwegala (1529m), Kalupahana (1628m), Labullessapatana (1222m), Lahumanagala (1100m) and Rambukkoluwa (1113m). The steep slopes found around the main ridge and all its extensions define the drainage patterns of the Hasalaka Oya, Teligam Oya, Heen Ganga and Kalu Ganga. These streams have formed gorges in places, which, as will be outlined later, play an important role in Its ecology (Giragama & Wickramaratne, 2005).

The range also has a number of long escarpments, the two most notable being the Little World's End at Deanston and the Mini World's End at Pitawala Patana (Cooray, 1984). These offer excellent views of the adjacent low-lying areas, attracting many sightseers annually.

Red Yellow Podzolic soil type is the most dominant in the Knuckles region. This is synonymous with much of the Wet Zone (Moorman and Panabokke, 1961). However, soils tend to be comparatively thinner with lower levels of nitrogen than in areas at lower elevations. It is likely that this affects the growth of vegetation in the area, contributing to the stunted and 'bonsai' nature of the forest trees. Soils here have also been observed as having high aluminium and organic carbon levels (Werner, 1988). This high carbon is most likely to be due to the slow rate at which organisms break down fallen leaf litter in the area, a feature related to the cold and wet conditions in the forest.

Soil profile characteristics differed, however, according to land use types in the

region. Cultivated land, most commonly found as part of a tea or cardamom estate, was found to have a considerably thinner 'A' horizon (the upper-most layer of soil) than adjacent pristine forest areas (Giragama & Wickramaratne, 2005). It is believed that because the natural vegetation – which is adapted to preventing precipitation run-off as much as possible – has been replaced with far less adapted species and over time rainfall has washed away the upper layers of soil and their nutrient content. As soil fertility decreases, farmers will face problems in the future. This soil erosion may even have begun causing problems already, such as reduced crop quality and quantity, or more serious problems such as flooding, drought and even landslides at lower altitudes.

Climate

As climatic parameters critically affect ecology, the study of climate is crucial to any ecological survey. Reptiles and Amphibians are particularly sensitive to climatic conditions, as they are cold blooded, relying on the sun to provide the heat necessary to function. In addition to directly affecting the habits of reptiles and amphibians, climate affects vegetation and accelerates erosion, leading to the development and diversification of landscape types. It is thus a key factor in determining the variety and quality of habitats in an area, thus indirectly affecting the fauna residing within.

Sri Lanka's climate is Tropical Maritime. It is further divided into three climatic zones: the Wet Zone, Dry Zone and an Intermediate Zone. Notably, all three of these climatic zones are present in the Knuckles range, a remarkable feature considering the relatively small area covered by the range (Rosayro, 1958). The mountains act as a climatic barrier, dividing the Wet and Dry Zones on its western and eastern sides respectively. Whilst some parts of its eastern slopes experience very low levels of rainfall, the region as a whole has the second highest annual rainfall in the whole of the Mahaweli watershed area (Bandaratillake, 1988). The majority of this precipitation occurs on the Wet Zone slopes of the range, and at high altitudes where the cloud layer forms. The rain gauging station in Kobonilla village recorded a yearly rainfall of 4 451.3mm in 1991, 41% above the wet zone average.

The action of the *'foehn effect'* causes the windward slopes in a mountain range to experience higher levels of rainfall than leeward slopes or low lying areas. As the Knuckles mountains are buffeted yearly by both of Sri Lanka's monsoons, one from the south west and the other from the north east, both sides exchange position as windward and leeward slopes (Giragama and Wickramaratne, 2005).

Unfortunately, very little meteorological data has been collected in the Knuckles region. There are no meteorological recording stations in the area and all but a handful of rain gauging posts remain. The two most prominent of these are at the forestry office in Illukkumbura and the longstanding station beneath Kobonillagala. The latter is situated in the rain shadow of the mountain Kobonillagala and thus cannot provide accurate rainfall data, which is representative of the entire region. In short, more research must be undertaken to analyse the meteorological systems at work here, not least for the development of meteorology, but also as a means for collating data in other disciplines, such as herpetology. Climate plays a major role in the ecology of reptiles, and thus to study reptile and amphibian behaviour, adequate meteorological data must be available. Project Knuckles faced this problem and hopes that it will be resolved in the future, facilitating long-term studies in the region. Furthermore, since the entire Knuckles area Is within the Mahaweli catchment area, it is of National interest to monitor meteorological data, as the area contributes to about 30% of the water in Victoria, Randenigala and Rantambe reservoirs of the Mahaweli river, as well as approximately 40 further smaller rivers. Climatic diversity in an area leads to the creation of a variety of different environments and ecological niches and therefore generally indicates high species diversity in that area. It is thus unsurprising that the Knuckles region, with

its climate "*ranging from the extreme wet to the almost dry*", (Rosayro, 1958) has a correspondingly high species diversity.

Vegetation

The flora of the Knuckles Mountains is unique. The vegetation types in the area are generally distributed according to altitude and position in relation to the lowland climatic zones of Wet, Dry and Intermediate conditions. For a general classification of forests, Project Knuckles divided the range into six forest types. Firstly there was the low lying Dry, Wet and Intermediate Zone forests, which were sampled only on occasion, such as to ascertain the presence of certain low-altitude dwelling species within the Knuckles Conservation Area. Then, from roughly 100 meters to 800 meters above sea level, forests were generally classified as Tropical Evergreen, on both sides of the range. From the elevation of 800 meters to 1 300m, Project Knuckles recorded forested areas as Lower Montane. All forested areas above this elevation were regarded as Upper Montane. For further detail on Vegetation types In the Knuckles see Chapter 2- Methodology.

Plate R1 - Knuckles and habitats

Figure 1 Montane forest ©JD

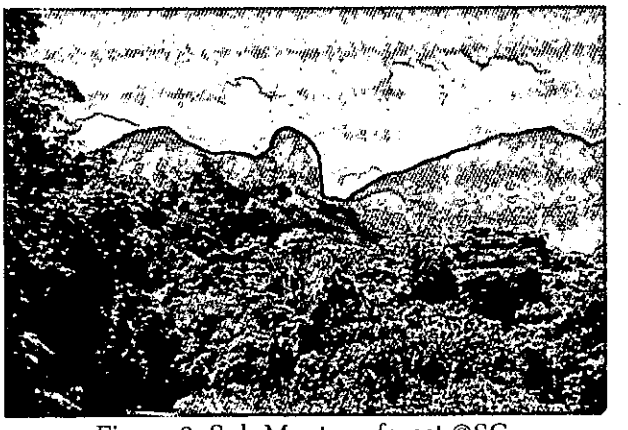


Figure 2 Sub-Montane forest ©SG

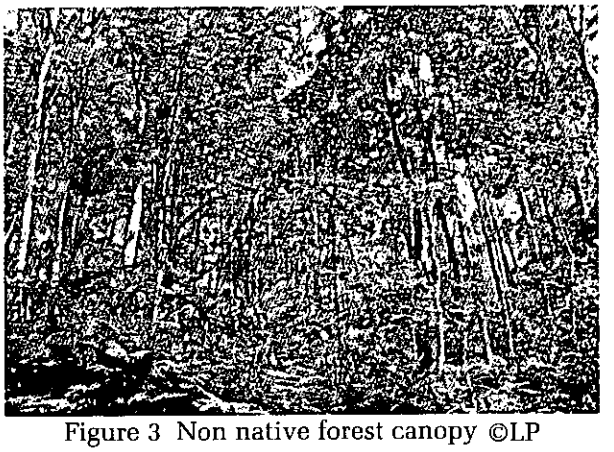


Figure 3 Non native forest canopy ©LP

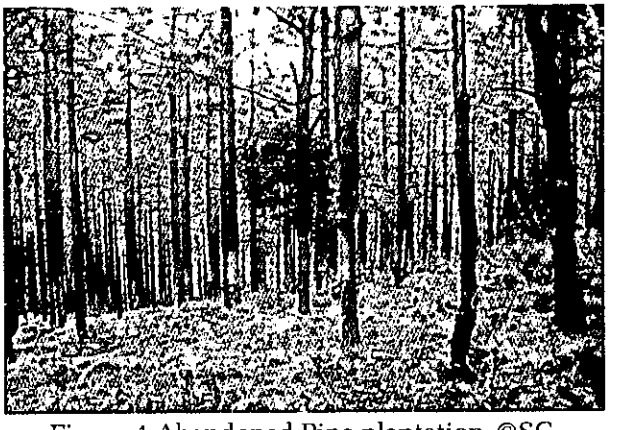


Figure 4 Abandoned Pine plantation ©SG

Figure 5 Acacia plantation ©LP

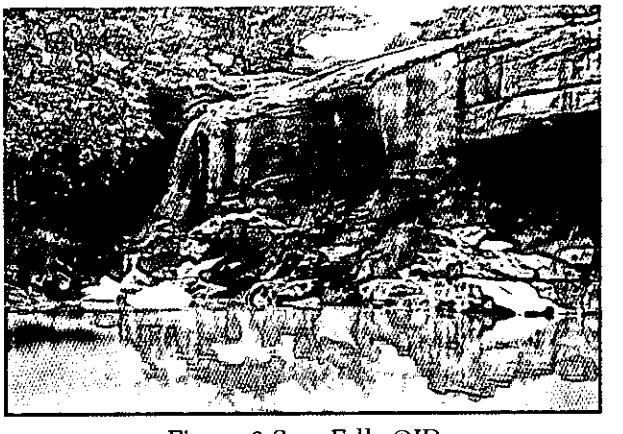


Figure 6 Sera Falls ©JD

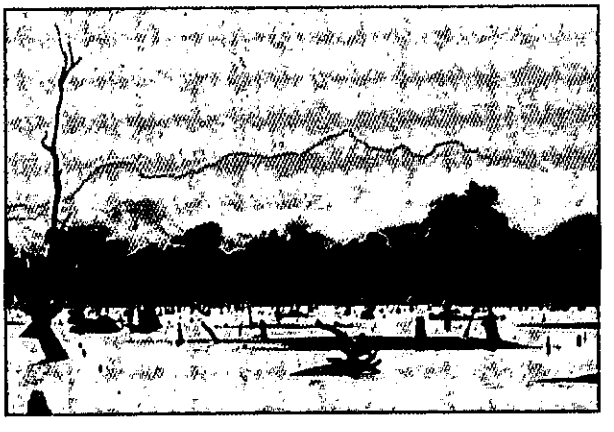


Figure 7 Dry zone tank (Namini Oya) ©SG

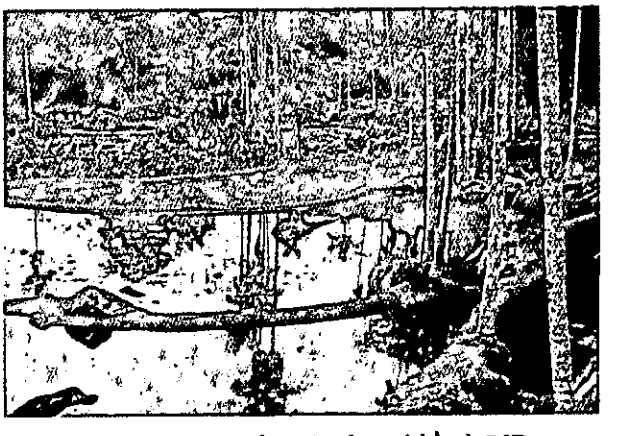


Figure 8 Typical agricultural land ©JD

Chapter 2
Methodology

The field techniques used to collate data during the Knuckles projects of 2004 and 2005 are very widely used in herpetology, which included: 1. Visual Encounter Surveys (VES), 2. Patch Encounter Studies (PES) and 3. Quadrat sampling (20 x 20m). In addition, canopy investigations were used as an experimental fourth technique.

The surveys were conducted so that the study could assess representative samples of all vegetation habitats and plantations (such as cardamom and pine) in the region as outlined in the end of this chapter.

Due to time restrictions and a sampling bias during Canopy and Quadrat Studies, these sampling methods were discontinued in 2005 and the project concentrated on Visual Encounter Surveys and Patch Encounter Studies, as they involve minimum disturbance to the natural environment and give a quick assessment of the surveyed habitats. The first two techniques were conducted during the day and twice a week at night.

1. Visual Encounter Surveys (VES)

This method tends to detect the most active and noticeable species. While walking, the fieldworkers 'scanned' the vegetation, path, and other possible places for reptiles, recording the species observed within a 3m distance from the path. Often, the field workers disturbed the leaf litter with the use of snake hooks, as leaf litter species emerge when slightly disturbed, which allowed them to be recorded. The mean yield per unit effort was calculated per species as per habitat, see Annex 3 for a summery. All specimens of interest encountered were caught and morphometric data such as snout to vent and tail lengths were measured using standard metric callipers (±0.1 mm precision); body weight was measured with a Pesola field weighing scale (±0.1g precision); and ecological data was recorded on structured survey forms.

After photographing, the animal was released back in its original place of capture. Ecological information gathered included sex, age class, colour variations, height from ground upon sighting, microhabitat, distance to sympatric lizards, injuries, defects, presence of ecto-parasites, reaction when caught, threats (presence of potential predators, habitat change etc.) and whether the females were gravid. GPS locations and environmental information was also noted at the beginning at the survey location and recorded in the structured survey form. The geographical co-ordinates and altitude in meters were measured using a Garmin eTrex GPS unit (±10m minimum accuracy), and percentage relative humidity was measured using a pen type digital thermo- hygrometer (± 1°C and ± 5% RH accuracy); air temperatures (1.5m above the ground), substrate temperatures and internal and external body temperatures of specimens were recorded in centigrade with a pen-shape "Digi thermo" digital thermometer (±0.1°C accuracy). Additional field notes were recorded in a field notebook. (See Plate R2 figure 1 for some of the above listed equipment).

All the above data will assist in the gathering of vital information on habitat requirements, species distribution and morphometric variability (Meffe and Carroll, 1997) and eventually help to construct Species Action Plans.

Amphibians and reptiles were identified (Plate R2 Figure 2) using Deraniyagala (1953), de Silva (1990), Dutta and Manamendra-Arachchi (1996), Greer (1991) and the Raffles Bulletin of Zoology No. 12, 2005.

Stool samples were collected in special vials with 10% formaldehyde solution. These were labelled and taken to the research laboratory of the Department of Veterinary Pathobiology, Faculty of Veterinary Medicine and Animal Science, University of Peradeniya, for further

investigations. For further details see De Silva *et al.* (2005f; 2005p).

Random stomach contents were taken for analysis from reptiles and amphibians using an intragastric cannula and distilled water. The distilled water was gently squirted into the stomach, while the mouth of the animal was held downwards, thereby flushing the stomach contents, which were collected in sterile bottles. The stomach contents were preserved in 10% formaldehyde solution and examined in the laboratory under a dissecting microscope.

2. Patch Encounter Studies (PES)
If it was known from available literature that a particular target species was abundant in a particular microhabitat or patch such as under logs, rocks and boulders of a certain size (i.e. *Nessia* species, *Chalcidoseps thwaitesii* and other sub-fossorial species) or inside cave systems and rock crevices (*Cyrtodactylus soba*), these specific microhabitats were checked. When one such target microhabitat was found in a particularly large abundance (such as a pile of rocks, or an abandoned building), the Visual Encounter Study would be temporarily suspended whilst the Patch Encounter Study was carried out. When sampling for fossorial species, additional environmental parameters were recorded such as the microhabitat soil hardness, using a penetrometer (pocket penetrometer model-STCL-3- see Plate R2 figure 4).

3. Quadrat Studies (20m x 20m)
In each selected habitat type (Upper & Lower Montane forests, Tropical Mixed Evergreen forests, Riverine forests, pine plantations, cardomom plantations and acacia plantations), a minimum of 5 randomly selected quadrats of 20 X 20m (0.04ha) was sampled. Representative areas of habitat (such as areas with no large number of invasive species or areas 5m away from the habitat edge to avoid overlapping 'edge' effects from neighbouring habitats) were selected for sampling. The quadrats were systematically searched by 6 fieldworkers* walking parallel paths across the area for 45 minutes, where all reptiles and amphibians observed were recorded (Jaeger and Inger, 1994). The survey was carried out between June 26th and August 19th 2004. In addition, all large trees inside the quadrat were climbed and checked for any arboreal reptiles and amphibians. The same 6 fieldworkers sampled all of the quadrats, to keep the sampling effort as unbiased as possible. Leaf litter was turned over and top soil to a depth of approximately 3-4 cm was checked for fossorial amphibians, reptiles and their eggs using a snake hook. Tree root systems, buttresses and holes were investigated with torches; rocks and dead logs were turned over (they were returned to their original position once searching underneath was completed).

The quadrat study was used as a more standardised method of evaluating species richness and species diversity within the sampled habitats that could be easily replicated for monitoring purposes in future studies.

Species diversity was calculated using the Shannon – Weiner diversity index $H = \sum Pi * \log_e(Pi)$, where the Shannon - Weiner index H is derived from the frequency rating Pi (i.e. from n/N, where n is the single species abundance and N the total abundance) and the natural logarithm of the frequency rating $\log_e(Pi)$. Index values for normal communities usually fall between 1 and 6. The higher the index rating, the greater the diversity, but as only reptiles and amphibians were studied in this work, it reduced the potential values. For further details see De Silva *et al.*, 2005b.

Sampling Habitats and locations:
Of all the habitats in the Knuckles listed below, during the study only the following were sampled in detail: the Upper Montane Cloud forest, Lower Montane forest, Tropical Mixed Evergreen forest, cardamom plantations and pine plantations. A total of 60 locations have been sampled in 2004 and 2005. (See map in Plate R18 indicating study localities). Due to time restraints, the following were not sampled in detail:

Riverine forests, Rock Outcrop forests, Patana grasslands and tea plantations.

Habitats in the Knuckles

The Upper Montane Cloud Forest

Upper Montane Cloud Forests are generally classifiable by their elevation. As they are defined by the layer of cloud which envelopes them for much of the day, and this layer of cloud forms at fairly regular altitudes, their distribution is therefore directly affected by the range of this particular altitude. Generally, Cloud Forests begin at different altitudes according to their global position. In Sri Lanka, the Upper Montane Cloud forests begin at approximately 1 400 meters above sea level. However, this rule is more suited to the Central Massif and does not fully apply to the Knuckles Range. On account of the *'Massenerhebung'* or 'Mass Elevation' effect, isolated mountains and ranges with peaks higher than the average in the area tend to experience cloud formation at a higher altitude in relation to their slopes. Thus, isolated mountains and ranges with peaks lower than the average in the area are more likely to experience cloud formation at a lower altitude in relation to their slopes. As the peaks of the Knuckles Massif are generally lower in altitude than those in the neighbouring Central Massif, the Massenerhebung effect dictates that cloud levels and the consequential conditions brought by this cloud will occur at lower elevations. Therefore the Upper Montane Cloud Forests of the Knuckles Mountains can be found forming as low as 1 300m above mean sea level (Giragama and Wickramaratne, 2005).

In terms of biodiversity, the Upper Montane Forests of the Knuckles are of extreme significance. Here exist 379 recorded plant species, 116 of which are endemic and 21 of which are threatened (Ratnayake, 2005). The pristine Cloud Forests are quite distinctive in their appearance. To begin with, the term 'Cloud Forest', by which they are commonly referred to derive itself from the layer of cloud, which forms around the mountains at high altitudes, mentioned above. When this comes into contact with the mountain surface, it forms a diurnal fog, a reservoir of airborne moisture. This humidifying agent also keeps the local environmental temperature low, thus allowing for a very different ecosystem to develop (Werner, 1982). This has a considerable effect on the vegetation, and thus the Cloud Forest is visually highly distinctive from adjacent vegetation types at lower altitudes.

The trees grow slowly here because of this low temperature, lack of photosynthesis due to the presence of the sunlight blocking cloud layer, and thin soils, with little nitrogen content and a limited supply of other nutrients. Meanwhile, the wind – often high at such altitudes – and its pressure upon the growth of the trees shapes them into bent and gnarled figures, although the degree to which this occurs depends upon the tree's exposure. It is more prominent on ridges and on the edges of the forest. The presence of fog also allows for the extensive growth of moss, lichen, ferns and various other epiphytic plant species. The abundance of lichen, gnarled trees and the silent nature of the woods – sound does not travel far in such conditions – has led to the term 'elfin' being used to describe them (Werner, 1982). In general, as altitude increases in the Knuckles Mountains, the vegetation experiences a decrease of leaf size and tree height and an increase in epiphyte concentration and species endemism.

Upper Montane Cloud Forests have a single story canopy where most flowers are found. The monopoly over light is held by this thick layer, preventing much plant growth beneath. The canopy experiences sharp extremes of sunlight, and as the bulk of a tree's foliage is at this level, it must develop certain protective mechanisms. In the early morning, for example, before the clouds form against the mountains, strong, damaging sunlight bathes the canopy. When the cloud layer does form, this sunlight is drastically reduced and the temperature drops accordingly. Perhaps as a response to this alternating bombardment and desertion of sunlight, the leaves of many Cloud Forest plants have developed a thick cuticle layer and other xeromorphic

adaptations (Foster, 2001; Werner, 1982). To date, however, it is not entirely known quite why xeromorphic adaptations have been adopted by the upper montane vegetation of the Knuckles. These are features normally associated with vegetation inhabiting more arid areas. The benefits these characteristics provide to the Knuckles flora have yet to be researched.

The Upper Montane Forests' unique adaptations to the mountain environment can also be demonstrated by the plants' tolerance of relatively low rainfall. Whilst a typical tropical rainforest requires at least 2000 mm of rain per year without interruption, the Cloud Forest can survive on 1500 to 2000 mm. This is almost certainly due to the action of 'fog-stripping' – the absorption of water from the diurnal fog layer – a remarkable feature of adaptation by the forest plant species. The high surface area of vegetation in the forest allows for more airborne moisture to condense and fall to the ground where it can be absorbed by tree roots. The lower temperatures brought about by this layer of fog also reduces evapotranspiration, thus lessening the need for water (Werner, 1982).

The thick vegetation in the Cloud Forest also helps to reduce the run-off speed of the rainwater. The benefits of this include the reduction in soil erosion and degradation from fluid action. It also acts considerably towards reducing both the risk of flooding and drought in lowland areas. When Colonial Secretary Sir James Emerson Tennent conducted his studies of the Knuckles Mountain Range in 1885, he concluded that where the hills had been cleared of trees – usually for coffee or tea plantations – drought and flooding had increased in the regions below. As some parts of the Knuckles, particular areas lying on the Wet Zone slopes can receive up to 5000mm of rain per year, the existence of Upper Montane Forests is crucial towards safeguarding areas lying below by delaying run-off (Werner, 1982).

In terms of biodiversity, the Upper Montane Forests are very notable, due to the presence of a selection of unique species, which have adapted to the unusual, finely tuned and balanced conditions present in such forest types. Endemism is common. This diversity can be accredited to the proliferation of epiphytic species, which have successfully adapted to the specific conditions of the forest. A third of Sri Lanka's endemic vegetation is found only in these unique conditions (Gunatilleke *et al*, 2004).

The importance of the epiphytic species can be outlined by their contribution to the forest Leaf Area Index. In general, this is 20 in most humid tropical forests, but with the presence of a successful community of epiphytic species, this index can increase to 150 on branches with dense epiphytic growth. Epiphytes can gather up to 50 000 litres of water per hectare through the action of 'fog stripping' as described above (Werner, 1982). This is an important drinking water source for animals inhabiting the canopy. It also reduces the rate of water filtration to lower altitudes, maintaining the regularity of hydrological flow in streams and rivers in lowland areas.

Some of the notable tree species in the area include members of the *Wienmanna* and *Cyatheaceae* families (Foster, 2001). *Rhododendron*, *Syzygium*, *Gordonia*, *Michelia* and *Elaeocarpus* species are also found throughout the range. Plants endemic to the Knuckles include *Stemonoporus offinis*, *Syzygium fergusonii*, *Eugenia cotinifolia*, *Brachystelma lankana* and *Obenonia walli-silvae*. Other rare plants which can also be seen in the range include *Eugenia rotundata*, *Helicia ceylanica*, *Dipcadi montana*, *Scolopia schreberi* and *Zanthoxylum rhesta* (Ratnayake, 2005).

However, the main tree species present at these altitudes are *Calophyllum trapezifolium*, *Calophyllum walkeri* and *Garcinia echinocarpa*. One can also find *Calophyllum cuneifolium*, *Gordoni ceylanica* and *Mastixia tetrandra*. These are the species which are prone to developing dwarfed characteristics and twisted branches in exposed areas of the peaks. Epiphytic species are also extremely

common, and as mentioned before, contribute massively to the high concentration of endemic species in the Knuckles Cloud Forest. Orchids, liverworts and filmy ferns are common in the region, making up a quarter of all plant species found in the Cloud Forest (Foster, 2001). Other shrub layer species include *Strobilanthes, Impatiens, Bamboo Indocalmus sp. Hedyotis* and *Gaertnera* species (Ratnayake, 2005). Certain species from the *Mystica, Cullenia, Litsea* and *Aglaia* families are found in the Knuckles range and not in the Central Massif.

Unfortunately, as these forests exist around mountain peaks, and do not extend below the cloud formation line at altitudes of 1 300 meters above sea level, they are usually found in isolated patches. The resulting environment is similar to an archipelago, whereby 'islands' of Upper Montane Cloud Forest are separated from peak to peak (Foster, 2001). These patches, harbouring ecosystems, which have been adapting and fine tuning for thousands of years are thus almost certainly subjected to the same threats as all fragmented forests, such as inbreeding, disease prevalence and forest fires.

Lower Montane Forests

This forest type is found between the altitudes of 600 and 1300 meters. It is the intermediary forest type between the Upper montane forests and the semi evergreen forests found at lower altitudes. On the eastern side of the Knuckles range, the dry zone climate has led to the development of a distinctive dry montane forest type, with a higher frequency of trees with small, waxy leaves, almost of a succulent plant nature. The trees are often pygmy in nature, with dense canopies reaching only heights of 15 meters. These features are an adaptation to cope with strong winds and high temperatures that considerably reduce the relative humidity of the environment. These conditions favour certain species of reptile. Snakes in particular appear more abundant in the dry leaf litter in these areas. On the western side of the Knuckles, facing the wet zone, the lower montane forests are less arid.

As these forests are found at lower, more accessible altitudes, they have been heavily degraded in parts by human activities. Many areas have been cleared for the cultivation of tea and tobacco. Also, in several areas, the shrub levels of the lower montane forests have been cleared for the cultivation of cardamom. As is the case in such instances in the upper montane forests, the canopy layer has been left intact, to protect the cardamom from the sun. As lower montane forests also act as catchment areas for a number of important rivers, the prevention of further degradation of the lower montane forests could be crucial in maintaining the current levels of irrigation and agriculture in large areas of lowland Sri Lanka.

Tropical Mixed Evergreen Forests

Below altitudes of 700 meters, the forests are more sheltered. The trees can grow to greater heights than those in the montane forests, usually about 20 to 25 meters, with an additional under-canopy layer of approximately 5 to 10 meters. There is often a layer of low vegetation at ground level. Species include *Crateava religiosa, Phyllanthus indica, Sterculia foetida, Bombex ceiba* and *Vitex altissima*. In the dry season of July and August, many of the trees shed their leaves. The well-defined layers of the forest canopy are well suited for arthropods, which in turn attracts a large faunal diversity, including birds, amphibians and reptiles. Tree girths vary greatly and many are well over a meter in diameter.

Riverine Forests

This forest type is found along the banks of rivers and streams. Due to the regular source of water the vegetation here is generally more developed than other forests in the region. Trees here tend to be taller and evergreen in nature, with the canopy layer ranging from 25 to 35 m in height. There is usually a sub-canopy layer of 15 m and a herbaceous layer of 0.5 to 3 m. Tree species such as *Terminalia arjuna, Madhuca longifolia, Mangifera zeylanica* and *Diospyros malabarica* can be seen here. As this forest type relies on a steady supply of water, it does not usually extend more

than 2 - 10m in width on either bank of a river. Many amphibian species can be observed in this forest type and many more vertebrates, including mammals such as Sambar and leopard can be observed in Riverine forests, especially during the dry season when they come in search of water. Riverine forests are extremely important to hydrological systems, as the root systems of the trees bind together the rocks of the riverbank, preventing erosion. It is very important that they are not disturbed.

Rock Outcrop Forests

These are scattered and fragmented forest types, formed due to the thin soil and rocky conditions on which they have grown. They are often dry and susceptible to forest fire and experience temperature extremes throughout the day. Floral diversity is therefore low, as only hardy species can survive. Exposure to strong winds can result in many of the trees being stunted. They can grow up to 15m, while the shrub layer can grow to 5m and the herbaceous layer, up to 1m. Again, these forests are important for the prevention of erosion. The root systems of the vegetation commonly bind soil together often on precariously positioned rocks. Due to the isolation and inaccessibility of many of these forest types, they are often frequented by elusive leopards seeking shelter.

Patana Grasslands

The Patana grasslands of Sri Lanka are a notable feature, readily seen at high altitudes where past human activity has cleared the forest. The patana grasslands are divided into wet and dry, according to altitude. The dry patanas exist between 915 and 1525m above sea level. They have a mean annual temperature ranging from 18 to 24°C. They are dominated by the grass species *Cymbopogon nardus* at the lower scale of this range and *Themeda tremula* at the higher scale (Premadasa, 1984). Scattered throughout the grass are isolated trees such as *Careya arborea* and shrub patches (Koelmeyer, 1957). The soils here are very poor, having been eroded by the elements with no forest to shelter or replenish them. They are highly compact and have very low levels of organic matter content.

The wet patanas exist above 1524m above sea level with a mean temperature of 15.3°C with a daily variation of 4 to 7°C. They are dominated by the grasses *Arundinella villosa* and *Chrysopogon zeylanicus*. There are also *Rhododendron* species standing in isolation, scattered throughout (Koelmeyer, 1957). The soil here is similar to the other less disturbed areas of the Knuckles range in that it is red-yellow podzolic and has a prominent A-horizon, quite unlike the dry patana (Moorman and Panabokke, 1961).

Tea Plantations

Tea (*Camellia sinensis*) was introduced to Sri Lanka before 1824 as an exhibitive specimen in the Royal Botanical Gardens at Peradeniya but it was not until 1867 that it was established on a commercial scale. At this time, much of the arable land of Sri Lanka was being extensively cultivated for coffee, but following the spread of blight and subsequent failure of the coffee crop, by 1889, the tea industry was set to flourish. In the Sri Lankan Highlands, tea grows at altitudes of 700 to 1300m and many Tropical Mixed Evergreen and Lower Montane Forests were cleared to allow for its cultivation. The resulting monocultures have been so vigorously managed that biodiversity is drastically lower than what was once present in the pristine montane habitat.

Cardamom Plantations

Native to South Asia, the perennial Cardamom plant (*Elletaria cardamomum*) produces an aromatic berry that is widely used as an ingredient in cooking, confectionary and traditional medicines. Whilst a species native to Sri Lanka exists, a strain from southern India is used for commercial cultivation on the island and the primary region for such cultivation is in the Knuckles Mountain Range. Here, approximately 55% of the country's cardamom crop is harvested. It is usually a subsidiary crop, whereby the farmer most probably has one other primary source of income.

The plant requires shade, cool temperatures and shelter from the wind. The former two

conditions are more readily accommodated at higher altitudes, where regular cloud cover keeps sun exposure to a minimum. However, to ensure shelter from the wind, further practices must be initiated by a cardamom farmer. Firstly, an area of forest must be selected and its lower levels of vegetation cleared. This includes shrubs, herbs and developing tree saplings (Navaratne & Madduma Bandara, 1993). The canopy is left intact so as to provide the third stipulation - shelter from the wind. The canopy also provides extra shelter from the rays of the sun, which can damage plant life in the region at times when the cloud layer is in recession.

Once the cardamom plants are fully grown, the farmer must continue to weed the area, removing all other competing vegetation. As the saplings of the natural trees are persistently removed, natural reproduction of the forest is thus prevented. Usually women and children are employed in the harvesting of cardamom berries. They can occasionally be seen walking hurriedly down mountain paths, carrying sacks of cardamom berries on their heads and backs. The berries are then taken to a cardamom barn where they are laid out on shelves above a source of heat. This process of drying the cardamom berries requires that they be heated for several hours. This process preserves them and is required before they are sold to dealers. However, the fuel used to keep cardamom fires burning is predominantly gathered from local tree species. This illegal activity is undoubtedly adversely affecting the forest ecosystems.

To counteract the damage of the cardamom plantations the Sri Lankan government began buying the upper slopes of the cardamom plantations from farmers in the Knuckles region. This was to allow the cardamom crop to die back and gradually become replaced naturally by Upper Montane tree species under the supervision of the Department of Forestry. However, once a cardamom plantation is abandoned, it cannot be reclaimed by pristine montane forest unassisted. Several years later when the taller trees die, there are no younger trees to replace them, since farmers have removed them. The cardamom loses its shelter and eventually dies back as well. It is then replaced, not by natural forest trees, but instead by species such as Bamboo, Lantana (*Lanatana camara*), Rattan and other weed species. These species are particularly competitive and once they have taken root are not easily removed. The nature of their growth renders virtually impenetrable the areas of forest in which they have developed and it is unlikely that natural forest plants are capable of contending with such voracious species. The forest remains permanently altered and disturbed.

Pinus Plantations

There are no species of conifer that are native to the montane forests of Sri Lanka (Abeywickrama, 1956). However, due to certain reforestation policies of the 1960s, a number of Pine plantations (*Pinus carebea*) exist throughout the country. The forestry department was then commissioned to plant large areas of Pinus around the range. Many argue that a species as foreign to the region as Pinus with such a different microclimate and soil characteristics, could not but damage the ecosystem. Project Knuckles, however, has demonstrated that certain species are adaptable enough to cope with this change, although only a small number of the original cloud forest inhabitants were found in the Pine plantation. Furthermore, the slow-decomposing pine needles are very prone to catching fire, killing off a large number of the less agile resident species. One of our studies was to assess the impact of these fires on the local reptile populations.

Canopy Sampling

Project Knuckles 2004 predominantly studied the forest floor and low-level forest habitats, but with the aid of forest canopy access techniques, the otherwise

inaccessible canopy was opened up for research. Our canopy research combined the most up to date and safest system known with local climbing expertise. Potential trees were examined for any herpetofauna by local climbers and trained fieldworkers (to a lesser extent) while ascending and descending a tree. Loose bark was examined and any crevices and epiphytes were carefully searched. See Annex 2 for in depth discussion (Plate R2. Figures 6,7 & 8).

The tree species was recorded along with height, girth and a diagram of the main branches. The types of epiphytes and creepers present were noted. The air temperature, relative humidity and wind speed was recorded at ground level as well as in the canopy. The presence and type of under storey vegetation and any logs and boulders were also recorded. They are of interest as many reptiles and amphibians occupy both the canopy and the forest floor, perhaps sleeping in the canopy and descending into low vegetation to feed.

Recommendations for future studies:
The next stage of study of the target species would require estimates of population or sub-population size. One of the main methods which could be used is a Mark and Recapture Study (Donnelly and Guyer, 1994). A representative sample area, perhaps of 200 x 200m is investigated, specimens caught are marked, then at a later date, the same area is investigated again and the rate of capture of marked versus unmarked individuals is recorded, assuming that each marked individual has the same probability of being caught as each unmarked individual. From this, it is possible to create models to estimate populations. One suggestion for marking includes using fast drying non-toxic paint to mark caught specimens, and using a coding system to identify individuals. This method is not thought to adversely affect lizard survival.

Plate R2 - Methodology

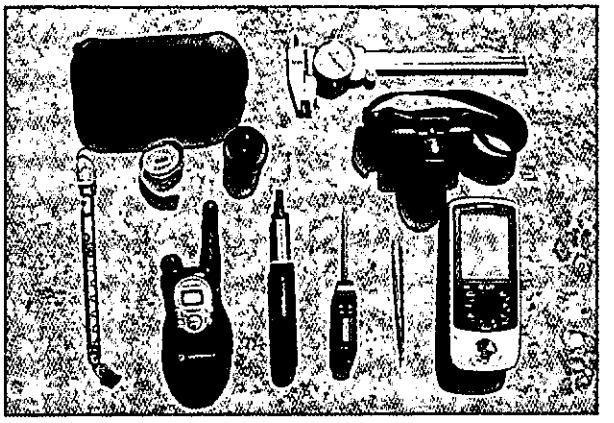


Figure 1 Some of the Field equipment ©JD

Figure 2 Scale counting ©LP

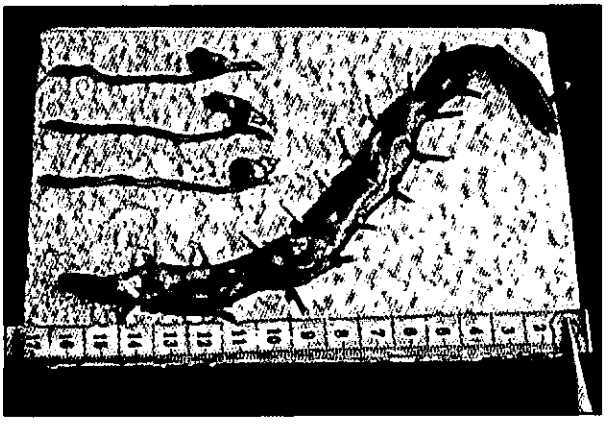


Figure 3 Dissection of a dead specimen ©LP

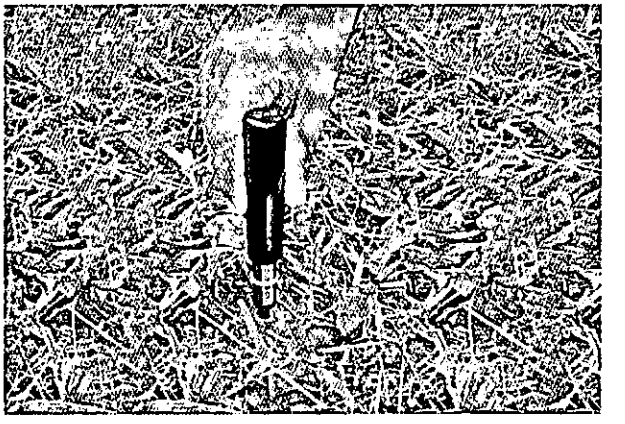


Figure 4 Penetrometer: measuring soil hardness ©JD

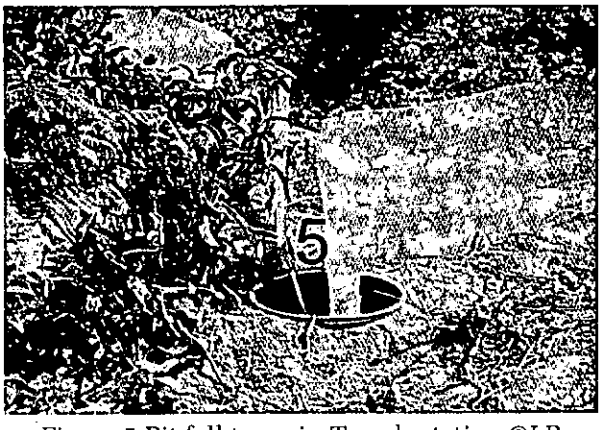


Figure 5 Pit fall traps in Tea plantation ©LP

Figure 6 Tree climber during canopy studies ©LP

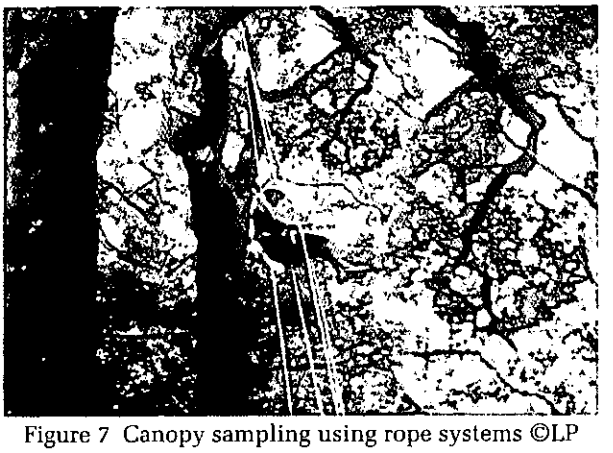


Figure 7 Canopy sampling using rope systems ©LP

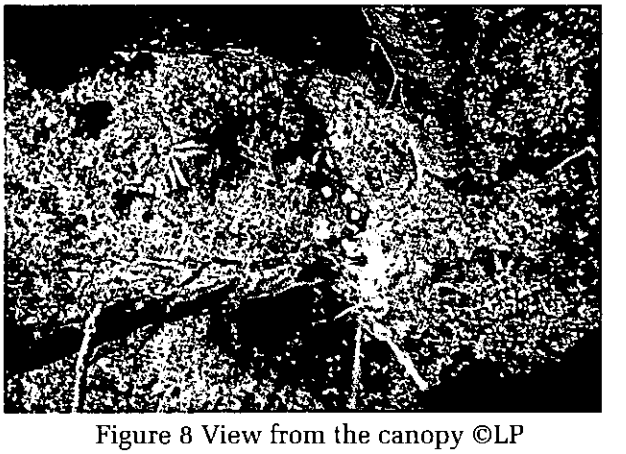


Figure 8 View from the canopy ©LP

Chapter 3
Agamids

Introduction

The agamids constitute a diverse and attractive group of lizards. Presently 17 species are known from Sri Lanka (Bahir & Maduwage, 2005; Bahir & Silva, 2005, Das & de Silva, 2005), of which the study targeted only those listed in the IUCN Red List of threatened animals for Sri Lanka (such as *Ceratophora tennentii* & *Calotes liocephalus)*. Other species that were considered vulnerable, as well as geographical relict species (Crusz, 1986), such as *Lyriocephalus* and *Cophotis* were also investigated. For a comparison of the Agamid species observed by various authorities in the Knuckles, see De Silva *et al.* (2005a).

Family Agamidae Gray, 1827

Ceratophora tennentii (Günther & Gray in Tennent, 1861)
The Leaf-nosed Lizard

Status

Ceratophora tennentii is one of fourteen species of agamid lizards endemic to Sri Lanka. It is known in Sinhala as the Pethi Angkatussa, meaning leaf (flat)-horned lizard, and in English as Tennent's horned lizard or the Leaf-nosed lizard. All names refer to the scaled, elongated and laterally flattened rostral appendage on the snout of the lizard, its most notable phenotypic feature (Plate R3, Figure 1&2).

It was first described over 150 years ago, by A. C. L. Günther & J. E. Gray (in: J. E. Tennent, 1861, Sketches of the Natural History of Ceylon: p. 281), Types: British Museum of Natural History 1946.8.27.32-36 (syntypes; fide Denzer et al., 1997), ZMB 4774, 5119, "Ceylon" (= Sri Lanka). *C. tennentii* has received little attention since this time.

However, due to its confinement to the Knuckles Mountain Range and the threats associated with this range's fragile ecosystem – the Upper Montane Cloud Forest – the species has received the IUCN classification of ENDANGERED under criteria B1 and 2abcd. *C. tennentii* was the first agamid from Sri Lanka to be included in the IUCN Red List of Threatened Animals (De Silva, 2000). Bahir and Surasinghe (2005) believe the species to be the 3rd most Endangered *Ceratophora* species after *C. karu* and *C. erdeleni* concluding that its Area of Occupancy is less than 130km^2. *They* consider its conservation status to be B2ab(iii) derived using IUCN (2001) Red List criteria.

Morphology:

Table 1 summarises the morphometric data of *C. tennentii* observed in the Knuckles.

Table 1
Morphometric data of *C. tennentii*

Sex	Total length (mm)		Weight (g)	
	Mean± SD	Range (mm)	Mean± SD	Range (g)
Female	203.6 ±36.3(n=17)	155 - 277	8.9±3.0 (n=15)	2.0 - 17.0
Male	211.8 ±23.8(n=24)	176 - 261	7.2±2.5 (n=21)	4.5 - 15.25
Juvenile	81.8 ±20.1(n=7)	66 - 124	1.1±0.7 (n=8)	0.4 - 2.0

C. tennentii is highly polymorphic in colour. The cryptic colouration helps it from being detected by predators. During the survey a large number of variations were observed in the colour patterns of *C. tennentii*. This was also been noted by Senanayake (1980) and Taylor (1953). These variations appear to be influenced by the colour of the surrounding microhabitat. Specimens observed on cardamom stalks were usually green, those on the ground amongst humus were often black and those on the ground amongst leaf litter were mottled and brown. Specimens on trees and saplings generally mimicked the colouration of the tree bark. On three occasions a red or orange specimen was observed. It is believed that even these more unusual colourings were again affected by microhabitat, and that they were the result of bright leaf litter. On capture *C. tennentii* usually changes colour, displays an open mouth and often feigns death in an attempt to evade predators (Plate R3 Figure 3).

During the study a morphological feature was observed which was not reported in previous literature. A saddle like scale pattern on top of the pelvis was observed in some specimens in a number of locations (Plate R3 Figure 4), however, this feature

C. tennentii were encountered mostly in disturbed Upper Montane Forests (70.6%) and disturbed Lower Montane forests (18.8%). Most of these areas were cultivated with Cardamom indicating that cardamom cultivators have encroached original *C. tennentii* habitats. The species was found in less numbers in the following habitats: Pine Plantations (7.9%), Pristine Upper Montane Forests (2.1%) and Riverine Forests (0.6%).

was not observed on all specimens. The significance (origin) of this feature is not yet clear and further investigation is required.

Habitat and Distribution

The exact area of occupancy of this species has yet to be defined. During the survey 340 specimens (72 Males (21.2 %), 58 females (17.1 %), 174 un-sexed individuals (51.2 %) and 36 un-sexed juveniles (10.6 %) were observed. It was found that *C. tennentii* inhabit altitudes ranging from 760m to 1550m above mean sea level. Although due to time constraints the peaks weren't sampled, it is most likely that the species will be also found in the undisturbed Montane forests up to a height of 1900m on Gombaniya peak. The study has found that the population size gets smaller as the altitude increases. Bickford (1994) found similar trends, where leaf-litter plots showed the herpetofauna of a montane wet forest at an altitude of 2450-2800 m in Costa Rica was less diverse and abundant than at lower elevations.

Specimens were recorded by the project in a number of localities including Corbet's Gap (1021m), Dawattagalla (1344m), Deanston (1227m), Dehigolla (1179m), Dotolugala (1550m). Dumbanigala (1088m), Elkaduwa (1225m), Horakanda (1315m), Hunnasgiriya (1227m), Kalduriya (1300m), Karabaketiya (760m), Knuckles (1386m), Kobonilagala (1458m), Kobonilla (1191m), Nicola Oya (1034m), Rangala (1179m), Riverston (1251m), Sphinx Rock (1316m), Thangapuwwa (1497m) and Waitalawa (1033m). Pethiyagoda & Manamendra-Arachchi (1998) also found it at Laggala and on the Midlands Estate.

Despite previous beliefs that *C. tennentii* were restricted to inhabiting pristine forests, we observed them living in a variety of disturbed areas, filled with exotic invasive species such as thorny *Lantana camara* (Plate R3 Figure 5) and invasive toxic species such as *Laportea crenulata* (known locally as Maoussa). Observing 27 specimens of *C. tennentii* in an abandoned pine plantation (*Pinus carebea*) near the forest office at Deanston is noteworthy as this is the first time the genus has been recorded in such forest types (de Silva *et al.*, 2005d). This may be due to the pine plantation at Deanston being in close proximity to cardamom plantation areas below. Perhaps the *C. tennentii* came to this new habitat for foraging and basking. It was clear that the species was reproducing in the habitat as 3 juveniles / hatchlings were observed in the locality.

C. tennentii was found more commonly in disturbed habitats than in pristine ones. Majority of the specimens was found in disturbed habitats and only 7 in pristine ones. de Silva (2001) observed similar trends during Horton plains Herpetofanual assessment of the forest floor litter, where the species richness and species diversity values were greater in the forest dieback areas. Inger (1980a and 1980b) found greater species richness in logged forests and in plantations than in rainforests, and suggested possible environmental factors, (i.e. abundance of weed species) to be the cause of this difference. Similarly, Heinen (1992) found a higher abundance and species richness in the more disturbed sites in Costa Rica, but species diversity was greater in less recently disturbed areas.

This could be evidence on how adaptable this species is to change in its habitat. However, this high encounter rate may be due to the possibility that *C. tennentii* is more conspicuous to the human eye when it is in a disturbed area. Perhaps its method of camouflage is not as effective as when it inhabits more pristine forest areas. Other factors which may have contributed to a higher sighting rate of *C. tennentii* in areas of cardamom cultivation include the fact that cardamom farmers regularly weed the ground surrounding each cardamom plant. Removing this low vegetation denies the *C. tennentii* of a hiding place, making it easier for researchers to spot and identify specimens. However, this would not explain the high encounter rate in areas of abandoned cardamom cultivation, where the field layer had been allowed to re-grow.

C. tennentii was found to utilise the lower strata of the canopy and not the canopy at levels higher than 4m. Most of the specimens observed were seen on tree stems with diameters of under 15 cm at breast height, such as saplings (45%), cardamom stems (19%) and on leaf litter or on the ground (16%). The species was also found amongst Bamboo and Lantana, amongst other Low vegetation, on logs, rocks, trees and a variety of other microhabitats (including vines and pathways).

Natural history:
Behaviour

Thermoregulation activities of *C. tennentii* was first studied by this project with the use of copper models. The preliminary results presented in de Silva *et al.* (2005e) have shown that *C. tennentii* does not actively thermoregulate but operates at relatively low body temperatures that closely resemble the air temperature of their microhabitat.

The first thermoregulation study in Sri Lanka using six copper models placed in the habitat of the animal was conducted during project knuckles 2004. This technique was first conducted to study the thermoregulation activities of *C. tennentii*. The preliminary results have shown that *C. tennentii* does not actively thermoregulate but operates at relatively low body temperatures that closely track air temperatures (de Silva *et al.*,2005e).

Basking time appears to explain the approximate 2 degrees centigrade difference maintained between body temperatures over substrate and air temperatures. Although the difference was small, it was fairly consistent across the temperature ranges. This is unusual in a species that spends time basking. Most heliothermic lizards, for example, maintain greater differences between body and environmental temperatures at low temperatures, which then becomes progressively smaller as the environmental temperatures increase (Huey, 1982; Avery, 1982).

Remaining motionless, awaiting prey, the *C. tennentii* are sporadically bathed in dappled light throughout the day, depending on the cloud cover of that particular day. They appear to avoid full sunlight, perhaps as it places them in danger of predation, or because it would overheat this relatively cold-tolerant species. It appears that the only behaviour of the lizard which was affected by the sun was their nocturnal activity. Around sunset, *C. tennentii* were observed to climb to the tips of branches and the ends of cardamom leaves. Once in a secure

position, they would sleep until sunrise. This positioning is believed to be an avoidance mechanism. Suspended at the ends of the branches, the lizards are less likely to be discovered by nocturnal hunters, such as snakes, as they would be if they slept closer to the main stem of the tree or plant. All specimens observed were immobile from darkness and the first specimen observed to become active did so at around 06:40 hours (well after dawn).

C. tennentii are found in close proximity to each other. True figures are unknown as the specimens are well camouflaged, a feature on which they are highly dependent. They were observed to communicate their mood (such as excitement upon catching prey) and anger (upon capture for scientific measuring) by moving their rostral appendage back and forth, showing their teeth in the process. This was usually accompanied with changes in the specimen's colour pattern.

Early zoologists believed that the *Ceratophora* rostral appendage was to search for food (Kelaart, 1852), but there was no such evidence from our study. It possibly assists the species with foraging as an addition to its camouflage, as the appendage can be likened to an immature Cardamom berry.

Competition between specimens is likely. On the 28th September 2005, a number of observations were made regarding the conditions of *C. tennentii* specimens. Several were observed to have missing tail tips. This could be a direct result of inter-competition, with dominant specimens biting the tip of lesser specimens whilst competing for food, shelter or a breeding partner or the action of a potential predator. In a study of *C. stoddartii* at Horton Plains, of the 45 specimens observed, 42 had their tail tips missing (De Silva, 1999).

In 2004 one specimen was observed under a rock, similar to the observation made on *Lyriocephalus scutatus* in the Central Province (Goonewardene & de Silva, 2005), as hiding under rocks and roots is well known strategy adopted by reptiles to escape from predators. Juveniles were all observed on the ground, usually under the field layer where they were well hidden. The reason for this distribution could be because their camouflage is better on the ground. Also, the layer of low vegetation affords them good cover from predation from above. Direct predation upon the species was not observed during the study period. However, in areas inhabited by *C. tennentii*, both Merrem's Hump-nosed Viper (*Hypnale hypnale*) and Millard's Hump-nosed Viper (*Hypnale nepa*) were frequently observed. These snakes tend to inhabit areas under the field layer and are therefore in a good position to feed on specimens on the ground, especially the juveniles and eggs. Hump-nosed vipers feeding on reptile eggs are known and this was observed once during the study. A Green Pit Viper (*Trimeresurus trigonocephalus*) was observed on one occasion to inhabit the stems at the base of a cardamom plant. This placed the snake in a prime position to prey on *C. tennentii* which were frequently observed on cardamom stalks. Several specimens of *Boiga ceylonensis* were also observed, which are considered a main predator of agamids and geckos.

Whilst parasitic activity by leeches upon *C. tennentii* specimens has not been observed, a number of other ecto-parasites were recorded targeting *C. tennentii* species. Of the 340 specimens recorded, 8 were infected with *Trombiculid* mites. Most had only one (either on the rear axial, head or crest) but one specimen had 4 on its neck. Furthermore, on two occasions, mosquitoes (between 3 and 7) were observed attached to the back of a *C. tennentii*, although the specimens did not appear to react to this.

Faecal samples were also collected when possible. The specimen would defecate almost as a response to what it perceived as a threat. Defecation is a well-known strategy adopted by animals to deter potential predators. For the results of parasitological analysis see de Silva *et al.*, 2005f.

Diet

C. tennentii did not appear affected by the presence of other anthropogenic activities. Specimens were observed on paths as well as in close proximity to human habitation. However, several cardamom farmers admitted to having killed a number of *C. tennentii* individuals, believing that they eat their crop berries and flowers. Careful observations, however, clearly revealed that *C. tennentii* is not attracted cardamom berries or flowers, but rather to the insects which are attracted to the cardamom berries and flowers. It is conceivable that while catching insects, flower petals could have been ingested accidentally but stomach flushes and faecal analysis indicate that the species' is diet comprised largely of insects. Indeed, several specimens were observed eating ants, caterpillars (Plate R3 Figure 6) and cockroaches (Plate 3 Figure 6). An instance of a specimen expelling a green moth larva after catching it is reported by Rodrigo and Jayantha (2004). *C. tennentii* appear to digest their food well. During analysis of some faecal samples, much of the material was visually unidentifiable (Plate R3 Figure 7).

One individual was observed exhibiting cannibalistic behaviour which occurred in a pine plantation near Deanston. A juvenile resting on the ground was attacked by an adult which leapt down from the stem of a pine tree. The adult attacked the juvenile face to face and took it in its mouth by the head. It then returned to the tree stem with the struggling juvenile inside its mouth. The struggle lasted only a few seconds before the juvenile ceased moving. The adult proceeded to chew the juvenile's head for several hours. Whilst chewing, the adult's rostral appendage was held in an upright position, unlike its lateral resting position.

Reproduction

During thermoregulation studies, two specimens were observed mating (on the 4th August 2004 at 11:20) (Plate R3 Figure 8). The female specimen was dull brown and on a rock, while the male who was dull chocolate brown was on a small tree stem 40cm from the female. The event seemed to be triggered by the male, which jumped to the ground 10cm from the female and changed its colour to dark green. After 10 minutes the male came behind the female, held the female by its forelimbs and moved the female's tail upward using its right hind limb. The pair proceeded to mate for approximately 3 minutes before parting again. The male returned to its original position while the female ran away for cover. 7 gravid females were observed and on palpitation indicated that they had 2 to 5 eggs each.

Threats and Conservation

During the survey C. tennentii was found with minimal search effort, suggesting that population densities are substantial, at least in the areas of the Knuckles ecosystem surveyed. Only two recordings were made of *C. tennentii* mortalities. The first was the above-mentioned cannibalism and the second, a road kill incident, between Hunnasgiriya and Deanston. Senanayake (1980) suggests that pesticides used by Cardomom growers, which target the prey species of C. tennentii, may be poisoning this species. He goes on to suggest a "strong correlation between the incidence of pesticide use and the demise of known populations of this lizard". Furthermore, loss of natural habitats, fire, unfounded beliefs and subsequent wanton killings, the predation by domestic animals such as rats (*Rattus rattus*), cats (*Felis catus*), and other opportunistic animals such as Coucals (*Centropus sinensis*), Crows (*Corvus macrorhynchos*), Rat Snake (*Ptyas mucosa*) and Wild boar (*Sus scrofa*) have been identified as threats to the species. For discussion on the threats faced by *C. tennentii* and subsequent recommendations see Chapter 10 for more details.

Genus: *Cophotis* Peters, 1861.
Cophotis ceylanica (Peters, 1861)

Status:

The Montane Pygmy Lizard is known in Sinhala as the Kuru Bodiliya, meaning dwarf Chameleon or Kandukara Kurukatussa meaning Dwarf Mountain Lizard. It is a montane lizard endemic to Sri

Lanka, cited under nationally orientated guidelines as Highly Threatened in the IUCN 1999 list of threatened fauna of Sri Lanka and has been assessed as Endangered under criteria A1c and 2c by the Conservation Management Plan (CAMP 2000). Bahir and Surasinghe (2005) believe the species to be one of the most Endangered Agamid species after concluding that its area of occupancy is less than 60km^2. They consider its conservation status as being B2ab(iii) derived using the IUCN (2001) Red List criteria. The species is known to inhabit the Lower and Upper Montane forests of Nuwara Eliya, Horton Plains, Hakgala, the Peak Wilderness and the Knuckles mountains and is known to be found only at altitudes higher than 1500m above mean sea level. Currently *Cophotis* is believed to cover an area of under 20,000 km^2, of which it occupies less than 2,000 km^2 (IUCN, 2000). The species is susceptible to mass mortality, where large numbers of dead specimens have been found littering the ground (de Silva, 1996; Palihawadana, 1998). It is not yet known what conditions trigger such an event.

Cophotis ceylanica populations can be considered to be part of two geographically separated populations: one in the Central Massif (Horton Plains, Hakgala and Nuwara Eliya (from 1600 to 2100 m above sea level), and a small population in the Knuckles Massif. These two populations have been separated for several thousand years and some scientists now believe that the population inhabiting the Knuckles may have undergone speciation. Over time, the population here may have become genotypically distinct. Molecular studies, presently in progress, will hopefully confirm this. If found to be true, the *Cophotis* genus would no longer be monotypic and this new species will be considered under the 2001 IUCN Red List criteria to be Critically Endangered as its Extent of Occurrence is approximately 10km^2. Its habitat is severely fragmented due to the species restriction to high peaks, which are frequently isolated from one another.

Morphology:

Cophotis ceylanica is a small agamid and is noted as having no tympanum (Smith, 1943) and as the only Endemic Agamid of Sri Lanka. with a prehensile tail. In juveniles, the spinal crest is not extended and upright as it is with adults. It was observed to be congruous with the rest of the body.Following are some measurements of *Cophotis ceylanica* observed in the Knuckles. (Table 2).

Table 2
Measurements of *Cophotis ceylanica*

Sex	Maturity	S V mm	Tail mm	Total length mm	Weight g
Female	Adult	49.0	66.0	115.0	3.0
Female	Adult	37.0	61.0	98.0	2.0
Male	Adult	60.0	76.0	136.0	2.5
Male	Adult	57.0	74.0	131.0	2.3
Female	Juvenile	28.0	38.0	66.0	1.0
Male	Juvenile	27.0	35.0	62.0	0.8

Habitat and Distribution

Although appreciable numbers of *Cophotis* were observed in the Knuckles from the mid seventies until the late eighties during visits made by ADS, recent observations have revealed that the species has become extremely rare in the range. During intensive sampling (approx. involving 1430 man hours), only 6 specimens were encountered. Of these, four were adults and two were juveniles / hatchlings. Of all adult specimens sampled, two were male and two female. Specimens were found in only two localities: Dotalugala (1550m) and Kobonilagala (between 1090 and 1458m) which are in the south east of the Knuckles Range. This study did not find *Cophotis* to be common in home gardens (with or

without Cypress trees) as observed by Palihawardana (1998), who encountered two *Cophotis* specimens in the Knuckles after only 12 hours of searching. However, this study does not specify the exact locations in which these were found but the report diagrams suggest a similar location to those found by Project Knuckles.

These agamids were only found in a small selection of microhabitats, including trees, one of which was dead, where a juvenile was found. Two specimens, including another juvenile were also found on cardamom stalks (Plate R4 Figure 6). The highest specimen was observed 3 metres above the ground and the lowest 0.1 metres from the ground. Although after initial observations of a specimen's height from the ground were recorded, one was observed to jump onto the ground and disappear into a tree root system. One juvenile was on a toona tree (*Toona sinensis*) – exotic to the Knuckles. This tree was noted as being almost completely isolated from other trees in the area. It was surrounded by cardamom, the cultivation of which requires the thinning of trees. For the *Cophotis* to travel it would almost certainly have had to resort to either crossing on the ground or by jumping considerable distances through the canopy.

Natural history:
Behavior

One *Cophotis* appeared to assert its dominance over the tree in which it was observed. It emerged from the tree canopy (from a height of 8m, which was also the top height of the canopy in this location which was recorded as disturbed Lower Montane Forest with cardamom cultivation) and descended (1 metre per minute) to the lower branches where it first encountered a sub-adult female *C. liocephalus* specimen. The *Cophotis* paused on the same branch, moved its head up and down repeatedly and opened its mouth threateningly, whilst facing the *C. liocephalus* head to head. The *Cophotis* easily prevailed and the *C. liocephalus* swiftly jumped to a lower branch and retreated to the low vegetation beneath the tree. The second *C. liocephalus* did not encounter the *Cophotis* although it was also observed to leave the tree completely and was not observed to return. A *C. tennentii* at the base of the tree was unaffected by its encounter with the *Cophotis*.

The *Cophotis* used crocodile-like movements compared to the more fluid movements of the other sympatric agamids. While the confrontation was occurring it used its prehensile tail to hold on to a branch as it was windy at the time. However, it didn't seem to be affected by the strong winds to the same degree as the *C. liocephalus*. This ability is a primary reason why it can be considered a canopy species.

Highly adapted to the windy conditions in the upper parts of the canopy, the species has a prehensile tail which it uses to wrap around and grip onto branches. The species is characterised by the specialised use of its tail. However, it would appear that adults are more proficient in using it, whilst juveniles are more reluctant to rely on it as a limb for support. The adult *C. ceylanica* specimen mentioned above was observed traversing a branch in high winds. In the same tree were two *Calotes liocephalus* individuals and one *Ceratophora tennentii*. Whilst the *tennentii* was secured firmly onto the main stem of the tree, the *C. liocephalus* and *C. ceylanica* specimens were all at least one metre from the main stem. In the event of a strong gust of wind, both the *C. liocephalus* individuals would retreat to the main stem of the tree where the effects of the wind such as shaking of the branch were reduced. The *C. ceylanica* individual, however, remained on its course, confidently using its tail to wrap around the smaller branches which extended from the branch on which it was moving. The specimen appeared only marginally restricted by the high winds. The tail is characteristically banded black and white in colour. However, the purpose of this additional striking feature is not fully understood.

In captivity, the environmental temperature of *Cophotis* ranged from 20 to 26 °C (Tryon,

1977). Air temperature (n=5) in *Cophotis* localities ranged from 18.9 to 24.1 °C with a mean of 21.8 ± 1.9 (SD). The substrate temperature (n=4) ranged from 18.7 to 22.6 °C with a mean of 20.7 ± 1.7(SD). Relative humidity at five *Cophotis* localities ranged from 43% to 95% with a mean of 73.2% and standard deviation of 20.6. The height from the ground of six specimens ranged from 0.1 to 3 metres.

Diet

One specimen was observed inhabiting a dead tree which attracts a larger numbers of insects than live trees, in particular ants and termites which *Cophotis* appears to consume, although they avoid larger ants, most probably due to their painful bite. A juvenile was observed to encounter a leech but instead of attempting to eat it, the juvenile avoided it. In captivity, *Cophotis* were observed to eat crickets, mealworms and small earthworms, but this is probably because they were easy to catch in the cage (Tryon, 1977). Palihawardana (1998) observed the species to eat houseflies, fruit flies, mosquitoes and other small insects in captivity.

One individual was observed exhibiting cannibalistic behaviour whilst being prepared for photography. An adult male attacked a juvenile specimen from behind, gripping its pelvis in its mouth and slowly chewing for roughly 30 seconds before the authors intervened (Plate R4 Figure 7). Had this intervention not occurred, the final outcome of this attack remains unknown. It should be noted that the adult was not particularly willing to let go of the juvenile. Whilst in the adult's grip, the juvenile displayed signs of being in distress. It struggled and turned in an attempt to bite the adult's head but the adult merely closed its eye on the side which was being targeted and continued to chew. No distress cry was emitted by either juvenile or adult at any point. Once the juvenile was freed from the adult's grip, it appeared to have lost some of the ability in its hind legs but survived until its release back into the wild.

Defence

Cophotis is a diurnal arboreal species. The species is highly cryptic hence its synonym: the False Chameleon. It blends well into its montane canopy environment. Its colouration, usually mottled green with brown and grey, matches that of the surrounding lichens and mosses. *Cophotis* specimens were observed to display mood through changes in the colourations of their neck and mouth areas. Red and yellow colourations have been observed, the yellow when one *Cophotis* specimen was exhibiting threatening behaviour towards a proximate *C. liocephalus*. In captivity, juvenile *Cophotis* were observed to change colour much more readily than adults according to their environmental substrate, temperature and humidity. This was not evident in adults and is perhaps a defence mechanism for the more vulnerable juveniles (Tryon, 1977). The species' slow movements while creeping along branches are perhaps also a defence mechanism to avoid predators.

When cornered *Cophotis* was observed opening its mouth in threat, arching its body and exhibiting a menacing posture, but no specimen was recorded to bite a researcher upon capture.

During the daytime, *Cophotis* were observed adopting antagonistic movements if they spotted an approaching threat (Plate R4 Figure 5). The specimen will move very slowly to the opposite side of the tree in relation to the threat and will wait motionless in this position for some time until they deem the threat diminished or are disturbed again, provoking further action, such as an escape to the ground. On one occasion one specimen was observed jumping onto the ground and running into piles of rocks and complex tree root systems. One juvenile specimen was observed to climb a tree stem and out towards the tip of an extending branch as the sun set. Here, the specimen was observed to sleep upside down under a leaf, using its claws and tail to maintain grip (Plate R4 Figure 8). During the hour preceding nightfall, the specimen appeared highly preoccupied in finding a suitable

location in which to sleep. It repeatedly attempted to ascend different trees in search of a suitable location. Each time when it was retrieved by a researcher for photography and tests, its only goal seemed to be to reach a safe spot in which to sleep. It persevered in its search regardless of the number of times the researcher would retrieve it. The specimen did not appear overly concerned by the presence of humans in its immediate habitat, and once secure in its sleeping position did not display any attempts to evade approaching humans.

Reproduction

Cophotis is one of only two known viviparous agamid lizards (Smith, 1935) (Fitch, 1970). Reproductive biology of the species have been observed by Palihawardana (1998) and Tryon (1977) during captive breeding programmes involving three male and four female specimens in Nuwara Eliya (IRDP) and one male and two female specimens at the Fort Worth Zoological Park, Texas, USA respectively. Females have been observed to give birth to up to 5 young at a time (Deraniyagala, 1953 and Tryon, 1977). The latter goes on to explain that in one of his broods, the juveniles emerged coiled and covered in a thick but transparent membrane, some of them attached by an umbilical cord to a large dorso-lateral yolk sac. Whilst one of the specimens attempted to free itself from the membrane, it appeared weak and unable to do so. Important to note is that all the juveniles in this brood died (The reason for this birth defect could not be determined), compared to Palihawardana (1998) where several of his hatchlings were released back into their native habitats. It is believed that viviparity in reptiles is an adaptation to adverse climates. Whilst *Cophotis* is a sub-tropical species, it lives in a comparatively cold montane environment which has perhaps prompted the development of this reproductive feature. It is also believed that this feature is a relatively recent adaptation and that there are still biological structures present in both mother and juvenile such as the membrane and yolk sac attached to the less fortunate juveniles, which indicates an evolutionary heritage of egg laying in the species (Tryon, 1977).

Threats and Conservation

No *Cophotis* mortalities were observed by us, despite documented mass mortality events observed around Hakgala (1,500 m) and Nuwara Eliya (1,800 m) where hundreds were found dead within a few days in 1992 (de Silva, 1996; 2001; Palihawardana 1998). Although post-mortem and other pathological examinations were not conducted to ascertain the cause of death, an extended drought and high temperatures reported during this period are believed to have been a major contributory factor (de Silva 1996, Fernando and Chandrapala 1991). Deraniyagala (1953) records fluctuations in the population of some reptiles including *Cophotis*, but does not give any reasons for such fluctuations.

Over the last 20 years, 50% of the *Cophotis* habitat has been lost, mainly due to deforestation through anthropogenic activities. The remaining habitat of the species continues to be threatened by further deforestation, fire, climate change, drought, the use of pesticides, predation by birds, both wild and domestic and the little-understood phenomenon of 'canopy die back', whereby certain trees have been observed to die for unknown reasons in both Horton Plains and the Knuckles although in the latter it was observed to a lesser degree. The fragmented nature of the *Cophotis* populations leaves the species particularly vulnerable, although the lack of research available means that few reliable predictions can be made on the future of the species. For a discussion on the threats faced by *Cophotis* and subsequent recommendations see Chapter 8.

Genus: *Lyriocephalus* Merrem, 1820.

Lyriocephalus scutatus (Linnaeus, 1758)
The Hump-nosed Lizard

Status

Known in English as the Lyre Head Lizard or Hump-nosed Lizard, *Lyriocephalus scutatus* is the largest agamid in the country. It is known in Sinhalese as *Gatahombu Katussa*

(meaning Hump Snout Lizard) referring to its prominent scaled protuberance on the nose, as well as *Karamal Bodiliya (meaning* Crested Lizard), *Kandukara Bodiliya* (meaning Montane Lizard), and *Sondura* (meaning Beloved, a reference to a belief that the reptile is the manifestation of a dead lover). It is a monotypic species, endemic to Sri Lanka. The largest specimen recorded so far measured 175mm from snout to vent with a tail of 185mm (Goonewardene & de Silva, 2005).

It is both arboreal and terrestrial, although it is usually observed living in trees as opposed to on the ground. Published literature suggests that *L. scutatus* is mainly confined to patches of dense, high canopy Lower Montane and Tropical Mixed Evergreen forests (between 25 -1600m elevation), in the Wet and Intermediate zones of Sri Lanka. The current distribution of the species is from Dambulla, Gannoruwa, Hantana, the Knuckles, Kosgama, Matugama, the Peak Wilderness, Sinharaja, Udawattakele, and Wakarawatte. Of these, only the Peak Wilderness, Sinharaja, and Udawattakele are protected areas, while the Knuckles Conservation Forest status only offers limited protection (De Silva *et al.*, 2005a, Bahir & Surasinghe, 2005). Furthermore, the populations of *L. scutatus* are highly fragmented.

The IUCN classifies the lizard as Vulnerable under criteria A1c + 2c (IUCN, 2000). To date, however, research has been limited to informal sightings and general field study. Bahir & Surasinghe (2005), classify the lizard as Vulnerable under criteria B2ab (111) under IUCN 2001 Red List criteria. The same authors also state that its area of occupancy is considered to be approximately 800 km^2, compared to a previous estimate of over 2,000 km^2 (Bambaradeniya et al 1997). As a result of habitat loss, the species has been increasingly seen in home gardens located on the borders of forests (De Silva, 1996; Manamendra-Arachchi and Liyanage, 1994; Bambaradeniya *et al.*,1997).

Morphology:
Following are some measurements of *L. scutatus* observed in the Knuckles. (Table 3).

Table 3
Measurements of *L. scutatus*

Sex	Total length (mm)		Weight (g)	
	Mean± SD	Range (mm)	Mean± SD	Range (g)
Female (n=5)	216.4±34.1	160-245	33.4 ± 18.05	6-54
Male (n=5)	245.8±40.6	203-301	44.17±8.6	38-54
Juvenile (n=3)	70.67±1.5	69-72	2.17±0.29	2-2.5

It was noted that specimens recorded in the Knuckles appeared enfeebled in appearance when compared to other *L. scutatus* populations around the country. They appeared unusually unhealthy for specimens who appeared to inhabit such good habitats. For example, the mean weight of males sampled was 44.17g ± 8.61 (SD) with a range of 38 to 54g. In Ambuluwawa, another mountain in the central province where a *L. scutatus* fragment population exists, a similar study (Goonewardene & de Silva, 2005) found specimens with a mean weight of 49.52g ± 20.45 (SD) and a range of 23.0-91.0g.

Habitat and Distribution:
In the Knuckles, *L. scutatus* specimens were

observed between the altitudes of 214 and 1191m above sea level. Specimens were recorded by the project in a number of localities including Elkaduwa (748m), Horakanda (1191m), Illukumbura (754m), Kobonilla (1025m), Kaikawela (760m), Lakegala (434m), Rajagala (1033m), Meemure (638m), Pitawala (852m), Puwakpitiya (622m), Sphinx Rock (576m) and Uyangamuwa (214m). They were found most commonly inhabiting Tropical Mixed Evergreen forests (63.2%) and disturbed Lower Montane forests (31.6%). As well as inhabiting pristine habitats, they were frequently observed in isolated forest fragments, in trees close to the periphery of the forest, and in highly altered forest types, such as clove, tea and pine plantations. Residents in some of the settlements in the Knuckles reported *L. scutatus* in their property. They were frequently observed close to paths and roads, thus indicating that their behaviour is not severely affected by the presence of humans.

They were usually encountered on small tree stems with a diameter at breast height of less than 15cm (47%), although they have occasionally been observed in larger trees (21%). One adult male was sighted in a mango tree in a small forest fragment 500m from Kobonila. Although specimens were observed in leaf litter, on the ground and even under a log, it is most likely that these specimens were encountered while they evading capture (except one female and one juvenile-see account below). They are otherwise usually seen between 1 to 3 m above the ground. In Horakanda, one specimen was observed in a Lantana bush (*Lantana camara*).

Natural history:

Behavior

L. scutatus is a diurnal arboreal species. Specimens were observed in either dappled sunlight or shade. None were observed in direct sunlight.

On one occasion, a hatchling was found under a rock only 1.5m from the road. This is highly unusual behaviour for a *L. scutatus*, particularly as in this case the specimen was surrounded by biting ants which didn't actually appear to be biting the agamid. *L. scutatus* specimens were also observed in close proximity to wasps, for example in Puwakpitiya one was seen only 4 m from a large wasp nest. Other sympatric species include *Hypnale hypnale* and *Hypnale nepa*, where hatchlings have been observed in the leaf litter only 3 m away. *L. scutatus* inhabits the same areas as *Trimeresurus trigonocephalus, Ahaetulla nastus, Dendrelaphis tristis,* the Crested Hawk Eagle (*Spizaetus cirrhatus ceylanensis*) and the Common Coucal (*Centropus sinensisi*). These are all potential natural predators. Sympatric agamid species include *Calotes calotes, Calotes liolepis, Calotes liocephalus, Otocryptis wiegmanni, Otocryptis nigristigma* and *Ceratophora tennentii* - the latter which was observed sympatrically in Horakanda, Kobonilagala and Waitalawa.

It was noted that the species prefers to sleep on vertical stems between 1 - 2m above ground and less than 10cm diameter at breast height (taken from 4 measurements). Night sampling proved most effective for encountering this species, as they do not show antagonistic movements to evade discovery as they do during daylight hours (taken from 8 measurements).

Two of the specimens recorded had broken tail tips, suggesting intra-species competition or perhaps predation. Unlike most of the other agamid species recorded in the Knuckles, none of the *L. scutatus* specimens appeared to have any ecto-parasites, such as Trombiculid mites. A number of faecal samples were collected. On analysis, they were found to contain no endo-parasites, see De Silva *et al.*, (2005f) for further details.

Defence

Upon capture, 87.5% of the 16 individuals struggled hard, 12% bit in addition to struggling and 44% feigned death in addition to struggling. One did not struggle but bit its handler and feigned death. 12.5% showed no reaction upon capture. Also, in addition to struggling, one defecated, one

changed colour and one opened its mouth as a threatening gesture directed at the researcher.

Other unusual characteristics of the *L. scutatus* population of the Knuckles included the exhibition of unusual colourations when compared to other populations of the country.

Reproduction

One householder in Hunnasgiriya reported seeing a specimen laying eggs during August, on a soil embankment in his back garden. He later observed 11 empty egg shells. This was particularly notable as the egg laying site was surrounded by pine trees for a considerable distance, indicating that the species has the potential to survive in such a disturbed environment. During early September, a gravid female was encountered - the only one observed over the two year period. The specimen was observed on the ground in Rajagala, possibly about to lay eggs. She was exhibiting a cryptic colouration pattern and was well hidden in the leaf litter. 3 juveniles / hatchlings were observed during the month of September, indicating that *L. scutatus* lays eggs which hatch during the months of August, September and October in the Knuckles.

Threats & Recommendations:

The main threats to the species are loss of habitat and habitat fragmentation, which has resulted in the species being increasingly seen in home gardens, which in turn increases the risk of predation by domestic animals such as cats and opportunistic predators such as the Common Coucal (*Centropus sinensis*). There is evidence of smuggling of the species by foreign pet traders. Other threats include road kills and other wanton killings on account of certain rural beliefs. For discussion on the threats faced by *L. scutatus* and the subsequent recommendations see Chapter 8.

Genus: *Calotes* Cuvier, 1817

***Calotes liocephalus* (Günther, 1872)**
The Crestless Lizard
Status

Of the eight species of the genus *Calotes* in Sri Lanka, five are endemic. *Calotes liocephalus*, the Crestless Lizard or Kondu Datirahita katussa in Sinhalese, is one of them, and scientists know very little of its ecology. The IUCN has classified the species as Endangered, listing it in the Red Data Book under criteria B1 and 2bc (de Silva *et al*, 2000), and Bahir and Surasinghe (2005) believe the species to be the second most Endangered *Calotes* species after the newly described *Calotes de silvai*. They consider its conservation status as B2ab(iii) derived using IUCN (2001) Red List criteria.

The species is found in the Knuckles and Sinharaja. Of concern to scientists, the species range of occurrence covers an area of under 5,000 km^2, of which it occupies less than 500 km^2. The few populations are fragmented, both through the separation of the Knuckles and Sinharaja areas, and through the isolation of individual mountain peaks to which some members of the population are seemingly restricted.

Deraniyagala (1953) observed *C. liocephalus* in Peradeniya, Gammaduwa, Agrapatana and Pandula Oya. However, a 1994 study by Manamendra-Arachchi and Liyanage could only find *C. liocephalus* specimens in the Knuckles region (including Gammaduwa). Bahir (personal communication, 2005) confirmed observations in Agrapathana, although Manamendra-Arachchi & Liyanage (1994) and Bahir & Maduwage (2006) made no observations of the species in the Central Massif, indicating a significant reduction in the area of occurrence of the species. Individuals, females in particular (Plate 2 Figure 3) are similar in appearance to *Calotes calotes* and *Calotes liolepis* - two sympatric species – thus careful observation is required to correctly identify *C. liocephalus*. During the study it was found that *C. liocephalus* were referred to locally as *Kolapata katussa*, or green coloured lizard, a generic term which also

encompassed species such as *Calotes calotes* or *Calotes liolepis*. *C. liocephalus* (Plate R4 Figure 1) differs from these two species by having no supratympanic spines (Manamendra-Arachchi and Liyanage, 1994). Males also have five to six distinct coloured bands on their body (Plate 2 Figure 2).

Deraniyagala (1953) observed that there is no commonly known species-specific Sinhala or Tamil name for the species *Calotes liocephalus, Calotes liolepis* or even *Calotes ceylonensis*, despite the wide area of occupancy and visually conspicuous nature of the latter. It is believed that this is due to the uncommon nature of the former two and elusive nature of all three species, whereby they are arboreal, live in forests, and display antagonistic movements when approached by humans (Erdelen, 1984).

Past research into the species has been general, limited to informal field recordings. Despite the belief that the species may be highly threatened and faced with the imminent prospect of extinction, studies to date have been all but minimal.

Morphology

34 specimens were observed during the expedition, suggesting that *Calotes liocephalus* is not uncommon in the Knuckles region. The morphometric measurements have been summarised in the table 4 below.

Table 4
Measurements of *Calotes liocephalus*

Sex	Total length (mm)		Weight (g)	
	Mean± SD	Range (mm)	Mean± SD	Range (g)
Female (n=8)	263.4±43.7	203-317	13±4.9	7-19
Male (n=4)	324.5±52.4	251-375	14.75±10.25	7.5-22

When observed in the forest they are normally bright green, sometimes with five to six darker bands on their body and a banded tail. However, if disturbed, particularly if caught, they often turn black. 2 specimens have been observed with 4 white dots on their back. One specimen (Plate R4 Figure 2), caught at Gammaduwa on the western side of the Knuckles Massif, was observed with 6 white dots on its back. In addition, it was observed with a rarely seen "rudimentary spine above one ear" (Manamendra-Arachchi, 1990; Deraniyagala, 1931).

C. liocephalus juveniles are green with olive limbs and faint dark rings on the tail. There are usually three white cross bars on their body in keeping with the colouration patterns of adult specimens (Deraniyagala, 1953). *C. liocephalus* hatchlings have been observed to nod their heads, indicating that this activity is not sexually orientated (Deraniyagala, 1953).

Habitat and distribution

Specimens were recorded in a number of localities including Dumbanigala (1049m), Sphinx Rock (1359m), Nawanagala (1199m), Corbet's Gap (1021m), Kobonilagala (1458m), Thangappuwa (1300m), Rangala (1164m) and Gammaduwa (1115m). 7 specimens were adult males, 17 adult females, 4 were unsexed adults and 6 were juvenile / hatchlings. The gender of the remainder could not be ascertained as they either could not be caught or were too young.

The majority of specimens were observed in abandoned cardamom plantations in both Upper (68%) and Lower (16%) Montane Forests. Initially believed to be a forest-dwelling species, *C. liocephalus* was also observed in tea estates (4%) and abandoned human habitation (12%),

frequently with little or no forest cover. They appear to prefer areas with large amounts of dappled sunlight, and were often observed where there was a break in the forest canopy.
The species was only observed in highly disturbed and modified ecosystems, and it was not observed in pristine environments. They were frequently found adjacent to paths and even roads. The species was most commonly observed inhabiting live trees (32%), dead trees (8%) and tree saplings (8%). These trees tended to have a diameter of less than 15cm and many were less than 4m in height where specimens were observed basking in the top branches where they had a good field of vision of the surrounding area.

The second most common microhabitat was in low vegetation (28%) (Plate R4 Figure 3) such as Mist flower (*Eupatorium reparium*) and Lantana bushes (*Lantana camara*). Despite being arboreal, the species was also observed on the ground (8%), usually under the cover of low vegetation. Although Lantana and Mist flower are exotic to the Knuckles range and believed to be damaging to the natural vegetation of the region, *C. liocephalus* appears largely unaffected. This may be because these invasive species have created new foraging habitats for the lizard.

The species has been observed in a number of surprising microhabitats, including a wall in an abandoned cardamom barn (Plate R4 Figure 4), amongst ferns, on a path and in a tea bush close to the forest edge. One was recorded in a vertical position on a large tree with its head facing towards the ground, indicating that it had travelled from the canopy – perhaps its preferred habitat type in pristine environments. The reason that they were often observed in disturbed habitats could be due to a sampling bias, whereby specimens inhabiting low vegetation are easier to spot than those in the trees, particularly those in the canopy. Further research is thus required to ascertain whether or not there is a sampling bias or if indeed this species is more successful in disturbed habitats.

Natural History Behaviour

The species was observed to live sympatrically to *Cophotis ceylanica, Ceratophora tennentii, Calotes liolepis, Otocryptis wiegmanni, Lyriocephalus scutatus, Uropeltis phillipsii, Cyrtodactylus soba, Chalcidoseps thwaitesii, Hypnale hypnale, Hypnale nepa, Trimeresurus trigonocephalus, Lankascincus* species, *Godiye* ants and grasshoppers. One late gravid female was observed on the ground under the cover of ferns, only a few metres from a *Hypnale nepa*, which would pose a significant threat, especially if the *C. liocephalus* was trying to lay eggs, as was suspected.

The species appears much more docile than other *Calotes* species. When approached by a researcher, specimens in trees where quite happy to jump out of the tree, either to a neighbouring plant or even sometimes a considerable distance onto the ground. However the species is slow moving and once on the ground is not particular adept at evading capture by researchers.

Intra-specific interactions were observed during research. Two adult males were observed approaching one another through low vegetation within a distance of 4m between them August 12th, 2005 on the Rangala road near Corbet's Gap. On being disturbed by researchers one ran away whilst the other held its ground and was subsequently caught and measured. It is possible that on encountering one another, these two specimens were preparing to fight, perhaps over territory as they were displaying their full colour patterns at the time and the one which held its ground was nodding its head. However, two *C. liocephalus* females, one sub-adult and one gravid adult were later observed in the same tree as one another, where they remained for several hours. The gravid female was only 75 cm away on an adjacent tree stem and the two appeared to tolerate one another although the gravid female was observed to grow darker when the two got closer.

It would appear that specimens inhabiting the canopy were adversely affected by the wind. They appeared to prefer to bask in dappled sunlight and forage for food towards the tips of small branches, usually one or two metres from the main stem - the above sub-adult female was observed feeding three times in such a position over a period from 09:00 to 15:00. The same specimen was also observed jumping distances of up to a metre 4 times whilst searching for food or better basking sites. Both female specimens were observed climbing rough and smooth barked trees. However, the individual would hurry back to the main stem of the tree should a strong gust of wind shake the branches, which was observed 6 times with the same individual over the same period of time. When one particular gust of wind shook the tree, one basking specimen was observed to return to the tree whilst a *Cophotis ceylanica* in close proximity and also subjected to the wind did not appear adversely affected and simply held its ground, using its tail to grip onto a small twig. Comparatively the *C. liocephalus* does not appear as efficient in moving around the canopy as *C. ceylanica*.

The same *C. ceylanica* specimen chased the two resident *C. liocephalus* females from their basking spots. It exhibited what appeared to be aggressive behaviour, bobbing its head up and down and opening its mouth whilst facing one *C. liocephalus* directly. The sub-adult female subsequently moved rapidly away from the *C. ceylanica*. The gravid female left the tree altogether and was not seen again.

Although feacal samples were collected from two specimens for parasitological investigations, analysis showed that they were free from any endo-parasites. One specimen was observed hosting a Trombiculid mite.

The tail tips of two individuals were broken. A further specimen's tail was observed to be kinked at the end, due to unknown causes. The specimen did not however appear impeded by this malformation.

One adult male specimen was found to have a puncture wound on its rear left thigh. It is believed that this was due to a bite received from another animal, but whether the other animal was a competing *C. liocephalus*, or another lizard or predator could not be determined.

Upon capture, 3 (17%) specimens emitted a distress cry. This was previously believed to be characteristic only of *Calotes liolepis*. 3 specimens were also observed to be shedding their skin during September.

Reproduction

Of the 17 female specimens, 5 (30%) were observed to be late gravid, with 2 to 4 eggs. No early gravid female specimens were observed during research. One *C. liocephalus* was observed to lay 3 eggs in August 1930 at Gammaduwa (Deraniyagala, 1953). Gravid specimens were recorded during September which may indicate that the species has a particular breeding season around this time.

Threats & Recommendations:

Two mortalities were recorded by the project. Two adult males were observed on the road near Corbet's Gap having been run over and killed by road traffic. One specimen was in 2004, the other in 2005 (with a total length of 332mm). This could be a regular occurrence, although the prevalence of scavenging species in the region means that numbers cannot be sampled accurately: victims of road kill may be quickly removed by birds, cats or ants before they can be identified.

The species is particularly vulnerable to both habitat loss and a decrease in the quality of the remaining habitats. Deforestation has resulted in the loss of 20% of the species' habitat in the last 10 years. The remaining montane forests which the species inhabits continue to be degraded by the cultivation of cardamom. Here, lower levels of vegetation are cleared for the cardamom crop, thus removing much needed low lying cover in which female *Calotes liocephalus* lays her eggs. Also, the fragmented nature of the remaining habitats means that the species

populations are isolated and concentrated into islands, whereby all the associated problems such as inbreeding and vulnerability to forest fire are heightened.

Other Agamids in the Knuckles Massif

***Calotes calotes* (Linnaeus, 1758).**

The Green Garden Lizard (Plate R5 Figure 3) is known in Sinhala as Pala Katussa meaning Green Lizard and in Tamil as Pachchai Onan meaning Green Lizard. It is not endemic to Sri Lanka.

Bahir & Surasinghe (2005) and Erdelen (1984, 1988), state that the species is common and widespread throughout the island from sea level to approximately 1,500 m in altitude. The project observed this to be the case in the Knuckles (235-1458m). In general, without actively searching for members of the species, over 100 specimens were observed, throughout the entire range. *C. calotes* is found mainly in anthropogenic habitats, including tea and pine plantations, rural gardens and chena cultivations. It was also recorded in tropical dry scrublands, mixed evergreen forest and abandoned cardamom cultivation in what are now heavily degraded upper and lower montane forests. They were encountered on low vegetation on the banks of rivers, streams and irrigation channels or on low vegetation along paths and roads and in anthropogenic habitats. In July 2005, five *Calotes calotes* females were observed laying eggs on the Narangamuwa - Lakegala trail. The females fled when disturbed and deposited a number of eggs whilst running. Agamids observed sympatric to the species were: *Lyriocephalus scutatus, Otocryptis* sp, *Ceratophora tennentii, Calotes versicolor* and *C. liolepis.*

An unusual colour variation of *Calotes calotes* was observed in the Knuckles (Plate 2 Figure 1) during the study. Presently work is in progress in order to ascertain the identity of these different individuals. A high incidence of road kills was also observed, this was the second most common agamid found to have been run over with 30 dead individuals recorded.

Noteworthy was an extremely large specimen (Table 5) which could be the largest on record to date.

Table 5

Location	Forest Type	Sex	SV (mm)	Tail (mm)	Weight (g)
Lakegala 718m	Tropical Mixed Evergreen Forest	Female (Gravid)	111	380	30
Elkaduwa 1130m	Lower Montane Forest	Male	124	431	47

***Calotes ceylonensis* (Müller, 1887).**

The Painted Lip Lizard (Plate R5 Figure 4) is known in Sinhala as Thola-visituru Katussa. The species is endemic to Sri Lanka.

Bahir & Surasinghe (2005) and Erdelen (1984), state that this is an uncommon species restricted to the Dry Tropical forest and Scrub forests of the island from sea level to around 400m altitude. However in the Knuckles appreciable numbers of this agamid was observed, which were mainly confined to the Tropical Mixed Evergeen forests, home gardens and chena cultivations, mainly on the trunks of mango trees, near the edge of the forests of the north eastern slopes of the range around Laggala-Pallegama, Kaikawala, Puwakpitiya and the eastern slopes around Bathalawatta, Yahangala, Sulunuge and Liyangolla. 25 specimens were observed during the study, all were on trees with a girth at breast height of over 15 cm. They were usually found between 1 to 4 metres above the ground. Five

specimens were measured, and were found to have total lengths ranging from 196 to 251 mm. Two specimens were weighed; one was 8.5g and another 10g. The air temperature at the site of 5 specimens ranged from 27.2 to 33.8 °C, whilst substrate temperatures ranged from 26.3 to 31.0 °C.

***Calotes liolepis* (Boulenger, 1885).**
English: Whistling Lizard, Forest Lizard (Plate R5 Figure 5), Sinhala: Sivuruhandalana Katussa. Status: Endemic.

Bahir & Surasinghe, (2005),and Erdelen (1984) state that *Calotes liolepis* is an uncommon species classified as Vulnerable under the IUCN(2001) Red list criteria B2ab(111). It is restricted to Wet Zone forests (Manamendra-Arachchi and Liyanage, 1994) and Moist forests in the Dry Zone such as at Ritigala from sea level to approximately 1220m in altitude. However, *Calotes liolepis* was found to be a common species observed throughout the Knuckles at an altitude range of 434 to 1458m on and around Dumbanagala (1132m), Lakegala (434m), Corbet's Gap (1223m), Dawatagala (1344m), Deanston (816m), Dotalugala (1227m), Kalupahana (1002m), Kandegama (750m), Keena-Bommana (933m), Kobonilagala (1191m), Laggala – Pallegama (571m), Loolwatte (1191m), Nitre caves (662m), Pitawala (846m), Pitawala Patana (919m), Puwakpitiya (550m), Kobonilla (1025m) and Udadumbara (500m)

50 specimens were observed, and 38 specimens were investigated in detail: Of these, 23 were female, 8 were male and 7 escaped before their gender could be verified. It was notable that no juveniles were observed during both the 2004 and the 2005 study. The morophometric measurements have been summarised in table 6 below.

Table 6
Measurements of *Calotes liolepis*

Sex	Total length (mm)		Weight (g)	
	Mean ± SD	Range	Mean ± SD	Range
Female	253.7± 80.1(n=15)	139-483	11.2±3.9 (n=10)	5-16
Male	255.2±138.5(n=6)	92-483	13.8±6.1 (n=6)	6-20

Of 23 females observed, 10 were early gravid (43%), each containing between 2-4 eggs, suggesting a healthy breeding population inhabits the Knuckles. Males and females were occasionally observed living in the same tree.

These observations were most commonly made in highly altered habitat types, including *acacia*, cardamom and pine plantations. Specimens could be seen on large tree trunks by the road side as well as in home gardens (Table 5 and 6). The largest population was observed in a pine plantation adjacent to Hunnasgiriya, a few metres from the town and not more than 2 or 3 metres from the road. In this particular plantation, which was inter-planted with non-pine species, the *C. liolepis* specimens were found only on non-pine tree species. They were not observed climbing pine trees themselves. Every non-pine tree, however, had at least one specimen somewhere on its stem, up to 6 m above the ground. In tea plantations, they were observed inhabiting tree species which were taller than the tea bushes. Again, they were frequently observed very close to roads and regularly used paths. In more forested areas, such as in forests adjacent to cardamom plantations, some were observed inhabiting strangler vine species and one was observed in a mango tree.

Two male *C. liolepis* were observed dead on the road running parallel to a pine

plantation (*Pinus carebea*) having been run over by road traffic.

At night, *C. liolepis* displays notable sleeping behaviour. In forests, specimens were observed sleeping at the tips of thin branches, holding onto twigs, sometimes up to 8 m above the ground, usually just below the forest canopy. They appeared to prefer to sleep as far from the main stem of the tree as possible. This would appear to be a defence mechanism against predators. They were easily spotted with a torch and did not attempt to evade approaching humans. Of particular note, these sleeping specimens, found during searches by six field workers, could not be located during the day using the same number of field workers in the same area. They are very cryptic, either inhabiting the canopy or, should they descend to lower levels of the forest, displaying antagonistic behaviour, moving around the tree trunk to evade approaching humans. They were observed living sympatrically with the following agamids: *Lyriocephalus scutatus, Otocryptis wiegmanni* and *Otocryptis nigristigma.*

Upon capture, *C. liolepis* were found to be particularly aggressive in comparison to other species, notably *Calotes liocephalus.* Of all the *C. liolepis* caught, every specimen struggled and every specimen attempted to bite the handling researcher. Of 38 caught, 3 emitted a distress cry akin to whistling (8%), the characteristic feature of the species which earns its name as the Whistling Lizard.

The tips of the tails of 6 specimens were observed to be broken, possibly due to intra-species competition. One specimen had teeth injuries, possibly due to intra-species competition or to external species predation. Two specimens were observed to be infested with Trombiculid mites. One had 4 mites on its jaw.

A number of faecal samples were collected, which on analysis revealed that there were no endo-parasites (See De Silva *et al.*, (2005f) for further details).

***Calotes versicolor* (Daudin, 1802).**

The Common Garden Lizard is widespread throughout South Asia and is known in Sinhala as Gara Katussa which means house lizard and in Tamil as Onnan.

Bahir & Surasinghe, (2005) and Erdelen (1984) state that it is common and widespread throughout the island from sea level to approximately 1,400m altitude. It was observed this to be also the case in the Knuckles (181 to 1315m). The species was observed mainly in anthropogenic habitats such as plantations, home gardens, chena cultivations, roads/pathways, heavily degraded former forest and scrubland. Gravid females were observed during the study period.

Senanayake (1980) has noted that *C. versicolor* could be a threat to hatchlings of endemic agamids, as he has observed *C. versicolor* predating on *Ceratophora stoddartii* in home gardens in Nuwara Eliya (Central Massif). However, we have not seen any evidence of predation in the Knuckles. Further monitoring is recommended, as this species have been noticed along paths in very pristine habitats, where endemic species are found. A good example of this was a *C. versicolor* female being found in Upper Montane Habitat around Dotulugala at 1315m, where *Cophotis ceylanica* and *Ceratophora tennetii* are found.

This species is observed to be highly susceptible to road kills, as this was the most common agamid observed to be run over with 30 recorded specimens and many more unrecorded sightings of dead specimens.

Preliminary observations of the *Calotes versicolor* population inhabiting Pitawala Patana indicated that the population appeared different from the *Calotes versicolor* inhabiting other lowland localities in the Knuckles range(De Silva *et al.*, 2005c). Studies are presently being conducted to further examine this observation.

The air temperature at sites where *C. versicolor* were found ranged from 21.6 to 37.7 °C and substrate temperature from 26.4

to 37.5 °C. One specimen was carrying a Trombiculid mite on its rear leg and many had injuries on their bodies, such as broken tails, bite scars and one specimen had a blind eye.

Genus: *Otocryptis* (Wagler, 1830).

***Otocryptis nigristigma* (Bahir & Silva, 2005)**

The Black-spotted Kangaroo Lizard (Plate R5 Figure 6) is known in Sinhala as the Kaka Lapawan Tali Katussa, which means black-spotted pendant lizard, Pinum Katussa, meaning jumping lizard, Tali Katussa meaning pendant lizard and Kala Katussa meaning forest lizard. It is endemic to Sri Lanka.

62 specimens were observed, of which 20 were female, 19 were male, 3 were juvenile and 20 were unsexed adults. This recently described agamid was observed to be mainly confined to the dry northeast lowland forests of the Knuckles. A conspicuous external identification feature of *Otocryptis nigristigma* is a black spot on the dewlap, in contrast to the orange spot found in *Otocryptis wiegmanni* (Bahir & Silva, 2005). Its specific name *"nigristigma"* has been coined from the Latin, nigra meaning black and stigma meaning mark (Bahir & Silva, 2005). The species is recorded in literature to be found at elevations of up to 450m, but in the Knuckles it was observed between (214-750m), considerably higher than first described. The species is found mainly in Dry Zone scrublands, Tropical Mixed Evergreen forest and in anthropogenic habitats such as home gardens and chena cultivations. Specimens were found on the forest floor, rocks, the roots of large trees, low vegetation and on boulders along streams.

The total length of adults ranged from 180 to 249 mm and weights from 16 specimens ranged from 4 to 8g. The air temperature at sites where specimens were found ranged from 23.1 to 36.4 °C and substrate temperatures from 22.4 to 32.7 °C. One specimen was observed to have been burnt alive from a forest fire in Hettipola (Plate R5 Figure 7).

In some areas (Illukumbura, Lakegala, Pitawala and Puwakpitiya) a few specimens were observed with a mixture of with either an orange or a black spot on the dewlap, indicating an overlap of the two species (de Silva *et al.*, 2005c).

Bahir & Surasinghe, (2005), state that the species is widespread throughout the lowland Dry Zone of the island and that it is a very common species.

***Otocryptis wiegmanni* (Wagler, 1830).**

The Orange-spotted Kangaroo Lizard is known in Sinhala as the Gomu Tali Katussa, meaning the forest pendant lizard; Pinum Katussa, meaning the jumping lizard, Tali Katussa, meaning the pendant lizard and Kala Katussa, meaning forest lizard. It is an endemic species. Over 105 specimens were observed throughout the Knuckles, in disturbed

Lower Montane forests (approx 50%) as well as in both disturbed and undisturbed Tropical Mixed Evergreen Forests (approx 50%). Of these, 26 were female, 21 were male, 25 were juveniles / hatchlings and 33 were unsexed adults. Specimens were found on the forest floor, rocks, the roots of large trees, low vegetation and even on boulders along streams. During night surveys they were observed sleeping on the edges of branches between 1 to 2m above ground (Plate R5 Figure 8). *Otocryptis wiegmanni* was observed inhabiting an altitude range of 434 to 1267 m. The total length of adults ranged from 162 to 204 mm and the weight of five specimens ranged from 3.5 to 6.5g. The air temperature at 23 sites where specimens were found ranged from 17.7 to 32.1 °C and substrate temperatures from 19.5 to 31.5 °C. Six gravid females were observed with up to 4 eggs and one specimen was observed laying eggs on a foot path on the Lakegala trail in July 2004.

Bahir & Surasinghe, (2005), state that the species is widespread throughout the Wet Zone of the island (up to 1350m) where it is particularly common.

Plate R3 - *Ceratophora tennentii*

Figure 1 *Ceratophora tennentii* (male) ©LP

Figure 2 *C. tennentii* (male) ©SG

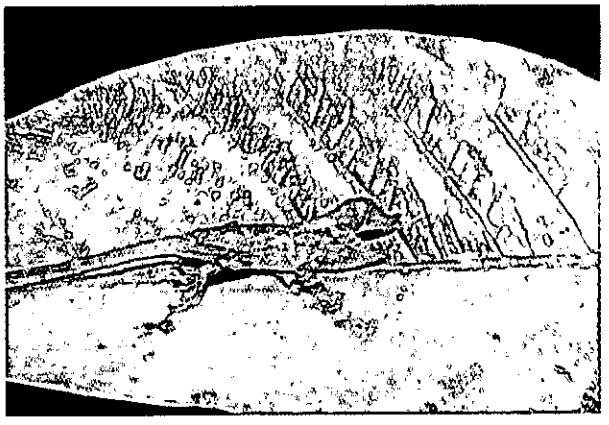


Figure 3 *C. tennentii* feigning death ©SG

Figure 4 Unrecorded morphological feature ©SG

Figure 5 *C. tennentii* in disturbed habitats ©SG

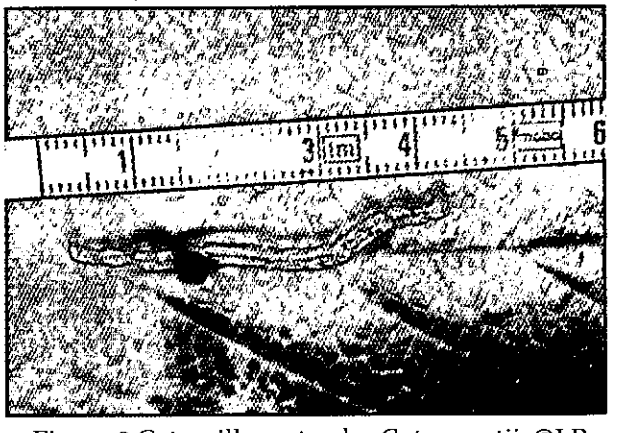


Figure 6 Caterpillar eaten by *C. tennentii* ©LP

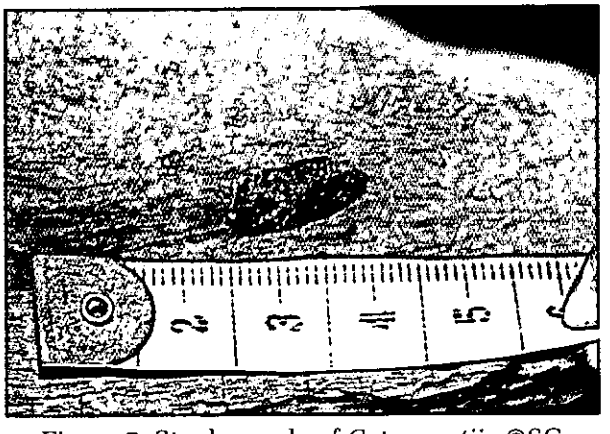


Figure 7 Stool sample of *C. tennentii* ©SG

Figure 8 *C. tennentii* mating ©LP

Plate R4 - *Calotes liocephalus* and *Cophotis ceylanica*

Figure 1 *Calotes liocephalus* (male) ©SG

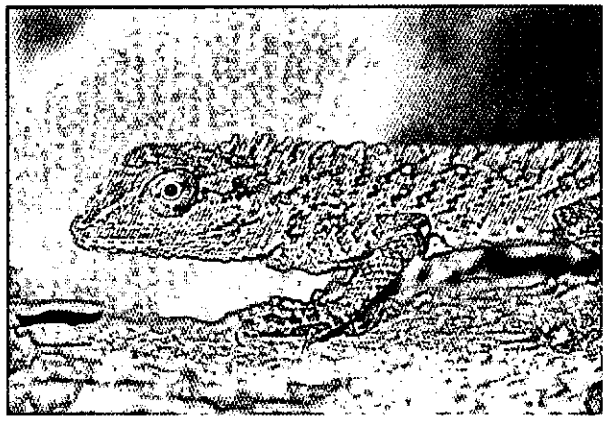


Figure 2 *C. liocephalus* (female) with rudimentary spine ©SG

Figure 3 *C. liocephalus* in disturbed habitats ©JD

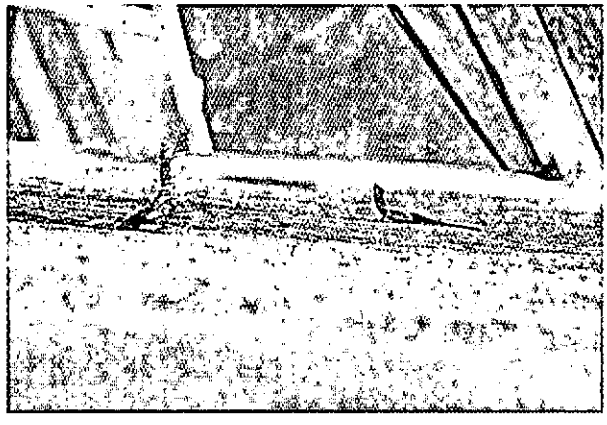


Figure 4 *C. liocephalus* on an abandoned building ©SG

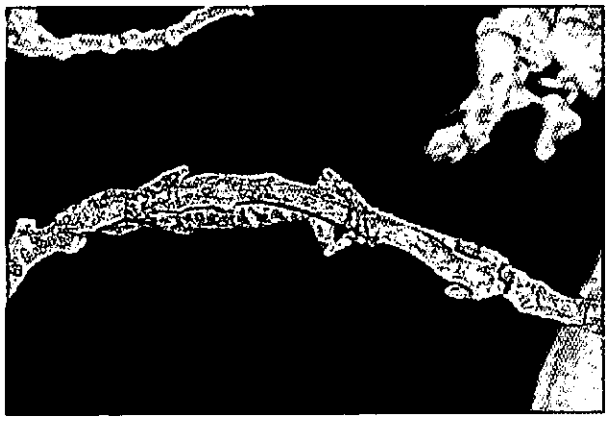


Figure 5 *Cophotis ceylanica:* cryptic behaviour ©SG

Figure 6 *Cophotis ceylanica* in cardamom ©SG

Figure 7 *Cophotis ceylanica:* cannibalism ©SG

Figure 8 *C. ceylanica* sleeping upside down ©SG

Plate R5 - Other agamids

Figure 1 *Lyriocephalus scutatus* (male) ©SG

Figure 2 *L. scutatus* (female) on ground ©SG

Figure 3 *Calotes calotes* (male) ©SG

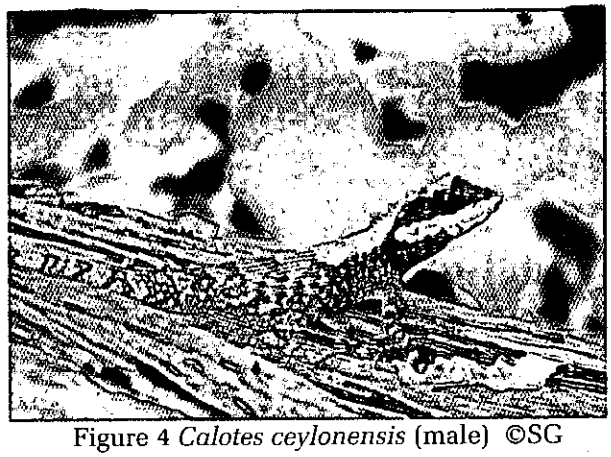


Figure 4 *Calotes ceylonensis* (male) ©SG

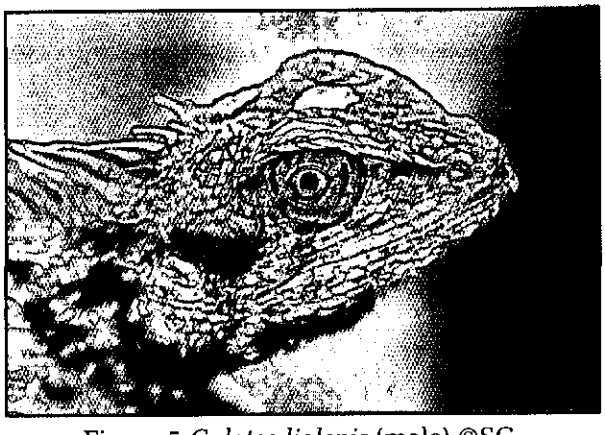


Figure 5 *Calotes liolepis* (male) ©SG

Figure 6 *Otocryptis nigristigma* (male) ©LP

Figure 7. Burnt *Otocryptis nigristigma* ©SG

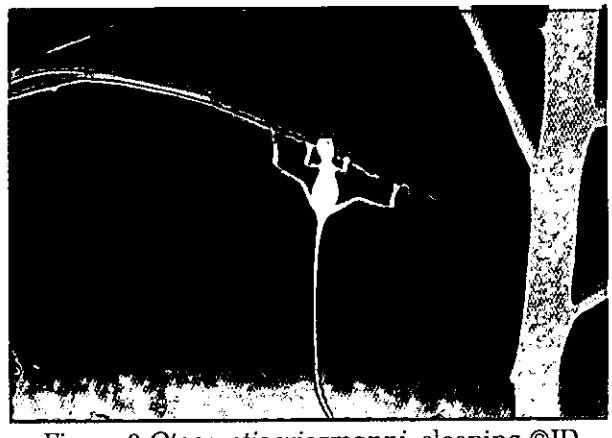


Figure 8 *Otocryptis wiegmanni* sleeping ©JD

Chapter 4
Skinks

Introduction

The Scincidae Family constitute the most numerous and diverse group of lizards. Presently 28 species are known from the country (Das & de Silva, 2005, de Silva 2001). This study targeted *Chalcidopseps thwaitesii* for detailed research as it is listed as an Endangered species in the IUCN Red List of threatened animals. However during the study a further 13 species of skink were found inhabiting various ecological niches in the Knuckles ecosystem. Some of these are considered to be Vulnerable in the CAMP report, following assessments using IUCN Red List criteria, (de Silva *et al*, 2000), some are further listed as Threatened in the 1999 National list of threatened animals (IUCN, Sri Lanka, 2000).

Family Scincidae Gray, 1827

***Chalcidoseps thwaitesii* (Günther, 1872)**

Common name The Four-toed Snake Skink and in Sinhalese: *Caturanguli Sarpayahikanala* or *Angili sathare heeraluwa*

Historical,

Chalcidoseps thwaitesii was first described in 1872 by Albert Günther as *Nessia thwaitesii* from a single specimen sent to the British Museum. Deraniyagala (1931) placed it in the scincid sub-family Acontinae, but it was subsequently reclassified to the family Scincinae by Greer (1970). Recently, Greer and Shea (2001) considered *Chalcidoseps* as exhibiting a possible relationship with scincines, which include the majority of reduced limb forms.

C. thwaitesii is a monotypic endemic species. The Conservation Assessment Management Plan (CAMP) classified the species using IUCN Red List criteria as Endangered under criteria B1 and 2bc (de Silva *et al*, 2000). The 1999 National list of threatened animals ranked it as Threatened (IUCN, Sri Lanka, 2000). Other reports considered the species to be rare (Ginige, 1994) and they were described as being "few in the range and fragmented" (de Silva *et al*. 2000). *C. thwaitesii* (Plate 7. Figures 1 and 2) is a geographical relict species that is found only in the Knuckles massif. The species is montane and fossorial, inhabiting the lower montane forests of the Knuckles – a protected area. The range of occurrence of the species covers an area of less than 500 km^2, of which it is known to occupy under 100 km^2.

Except for morphological features and brief notes on its ecology reported by Deraniyagala (1931, 1953) and Smith (1935) nothing is known of the species' ecology, population, distribution or conservation status. Past research on the species has been limited to informal field sightings.

Morphometry

A total of 88 specimens of *C. thwaitesii* were observed, of which 15 (17%) were adult male, 29 (33%) adult female, 13 (14.8%) juveniles and 31 (35.2%) unsexed adults, whose gender could not be verified as they were not caught or escaped before proper measurements could be taken.

The mean total length of adult males was 113.17mm ± 23.34, (Range 57-137mm, n=12), for females it was 113.65mm ± 22.15, (Range 71-159mm, n=23) and for unsexed juveniles it was 72mm ± 11.69, (Range 59-92mm, n=7). The total adult mean male weight in grams was 3.18g ±1.6 with a range of 1.0-7.0g (n=11), the female mean was 3.0g ±1.6 with a range of 0.5-7.0g (n=17) and the unsexed juvenile mean was 0.95g ±0.58 with a range of 0.5-2.0g (n=6,)

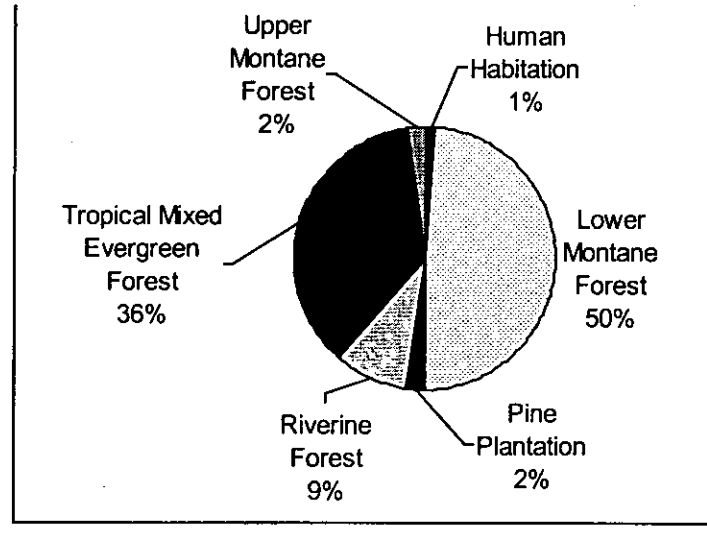
The difference was not significant between the total length of males and females (Two sample t-test, t = 0.06 P = 0.952 DF = 33). There was no significant difference between the weight of males and females (t = 0.26 P = 0.795 DF = 26)

Habitat and distribution

C. thwaitesii is widely distributed in the Knuckles Massif (Plate R18), but is found primarily in Disturbed Lower Montane

Forests (50%), with cardamom plantations (*Ellettaria cardomomum*) and Tropical Evergreen Forests (36%, Plate 7 Figures 3 and 4), within an altitude range of 242 to 1325m, (mean = 859.7m ± 230.4, n = 88). This species has also been observed in home gardens (2%) and in monoculture pine plantations (*Pinus carebea*) within the Knuckles. (Figure 1)

Figure 1
Habitat distribution pattern of *C. thwaitesii* in the Knuckles Massif



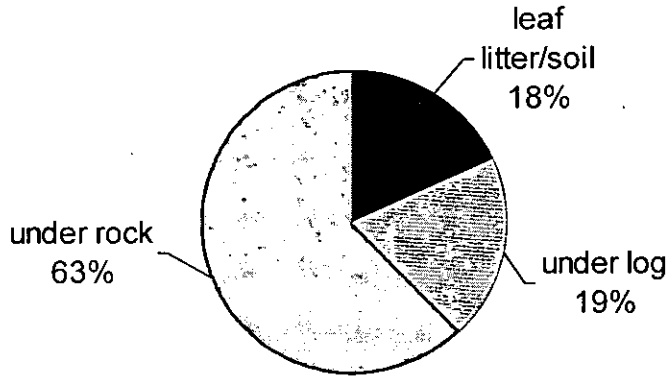
Specimens were observed at Bambugala (821m), Corbet's Gap (688m), Dehigolla (1153m), Dumbanigala (1049m), Gammaduwa (940m), Horakanda (1043m), Hunnasgiriya (1023m), Illukkumbura (638m), Kalupahana (1002m), Kobonilagala (1325m), Kobonilla (1074m), Lakegala (434m), Loolwatte (1191m), Maningala (754m), Meemure (600m), Nitre cave (550m), Pitawala (836m), Rambukoluwa (242m), Sphinx Rock (1313m) and Yahangala (770m). Ginige (1994) records it from Kalupahana and Rattota. However, Günther's (1872) record of a *C. thwaitesii* near Peradeniya, which is outside of the Knuckles Massif, needs to be confirmed for its accuracy, (see De Silva *et al.* 2005i for discussion). In addition to the central ridge of the Knuckles Range, the species has been observed in Gammaduwa, an outlying spur of the range. It is possible that the species spread to this area during a period when there was more forest cover in the region. Currently, Gammaduwa is practically an isolated fragment from the rest of the range. It is connected only by a very small area of forest at its north eastern extreme.

Our observations confirmed the species to be more sub-fossorial than fossorial, as 55 out of 88 observations (63%) of *C. thwaitesii* were underneath rocks (Plate 7 Figure 4). Logs (19%) and leaf litter / soil (18%) were the next most common cover items used.(Figure 2) It was also noted that *C. thwaitesii* specimens were often found in areas of high disturbance such as under rocks in the middle of human pathways. They were frequently observed in abandoned tea and cardamom plantations and were even found in pine and *acacia* plantations. They were also frequently found in forest fragments, many of which were considerably isolated from other forested areas. This was evident throughout the Knuckles Range, including

Gammaduwa and around the Deanston-to-Kobonilla road. A single adult was observed among the root system of a small tree on a steep bank of about 45 degrees inclination.

Of the 40 forest floor plots investigated (de Silva *et al,* 2005b), 21 specimens of *C. thwaitesii* were observed in 11 plots.

Figure 2
Microhabitat utilisation pattern of *C. thwaitesii* in the Knuckles Massif



In localities where 55 specimens were caught, the mean Air Temperature was 25.8°C, ± 2.5 and a range of 20.8 to 29.8°C. The mean Microhabitat Temperature where 41 specimens were caught was 23.8°C ± 2.4 and a range of 20.1 to 34.5°C. The difference between Air temperature and Microhabitat temperature is significant $F = 17.23$, $p = 0.000$.

The hardness of the soil (penetrometer reading) from 36 locations ranged from 0.25 to 3.0 per kg/sq.cm with a mean of 1.24 ± 0.8. However, random checks of the earth's hardness taken where *C. thwaitesii* was not observed ranged from 3 to 6 per kg/sq.cm.

Natural History
Behaviour
C. thwaitesii is a diurnal reptile (AdS, personal observations), in contrast to the statement by Crusz & Daundasekera (1988) that "they are most active at night". Captive specimens have been observed to be active in the early morning from around 0600 hours, (AdS, personal observations) but they showed very low levels of activity during the daytime, preferring to stay under cover. However, they were not observed at night in their natural habitat. It is suggested that further research be conducted to observe the behavioural patterns of this species during the night.

When *C. thwaitesii* are exposed by lifting logs and stones, they are very quick to slither away and creep into loose humus, soil, under leaf litter or stones, crevices, into holes in the earth or among root systems. They move primarily by sinusoidal wriggling movements, rather than by using their short four-toed limbs. When first handled 75% of them struggled considerably in an attempt to escape, while 19% of them defecated, while biting. Faeces were particularly pungent. Autotomy (Plate R6 Figure 2,3) and feigning death was observed in 10% of encounters. A further 3 specimens were observed with regenerated tails, suggesting that autotomy occurs even in the wild, and is most probably used as a predator escape strategy.
On five occasions, specimens were observed within close proximity of one another, several as close as 2 to 5 cm beneath the same rock. In an area of 8 m^2, 5 specimens were observed under stones which were 1 or 2 meters apart. In captivity, *C. thwaitesii* was

seen to attack and chase the common skink (*Lankascincus* species) when introduced to its cage. This suggests that *C. thwaitesii* is aggressive.

Sympatric invertebrates in the same microhabitat (i.e. under the same stone/log) were scorpions, ants (known locally as Kuru), pill bugs, spiders (twice), crabs, white termites (twice), spiders, millipedes (twice), beetle larva and earthworms. Sympatric vertebrates which were found to be under the same rock were *Lankascincus fallax* (twice), *Ramanella obscura, Nessia bipes, Lygosoma punctata, Geckoella triedrus, Hypnale hypnale, Haplocercus ceylonensis, Otocryptis wiegmanni, Uropeltis phillipsii, Uropeltis melanogastor, Rhinophis philippinus, Ramanella obscura and Typhlops* species.

Three individuals were observed shedding their skin during the month of September (Plate R6 Figure 2). Some specimens had white skin pigmentation in their tails, similar in appearance to a leukoderma (Plate R6 Figure 3).

A number of injuries were observed in several specimens. Missing toes were recorded in 2 specimens. Further injuries and scarring were observed on the bodies of a number of specimens. These injuries could suggest predation, but it is also possible that these specimens fight with one another.

Personal observations by Ads has shown that the species is hardy and could be kept alive in captivity for well over a year.

Food

It is believed that this species feeds on insects. In a few places where *C. thwaitesii* was observed, termite mounds, or termites (inside decaying logs or in the surrounding leaf litter) were found nearby. In captivity this species readily accepted termites as food. Termites have often been identified as a critical item in the diets of reduced-limbed skinks in many different habitat types (Huey *et al.* 1974). A few specimens were observed foraging in termite mounds, where termites were observed biting them, but the *C. thwaitesii* did not appear severely affected by this.

Reproduction

During the months of July and August, 10 of the 31(32%) females encountered were gravid and were found with 2-3 eggs. 13 juveniles/hatchlings were observed from June to September. Deraniyagala (1953) reported two soft shelled eggs collected in April from Gammaduwa. He described them as being somewhat kidney shaped with one end slightly more pointed than the other. They measured 18 x 6 mm and 18 x 11 mm and had been deposited in loose dark loamy soil in a cardamom plantation.

Internal and external Parasites

Five *C. thwaitesii* were observed with mites. During the present study, a number of faecal samples were collected. Analysis revealed that there were endo-parasites (see De Silva *et al.*, 2005f for further details).

Threats & Status

During the survey, we made observations on 88 specimens, with minimal search effort, suggesting that population densities are substantial, at least in the areas of the Knuckles ecosystem surveyed. Habitat loss, reduction of rainfall, application of agro-chemicals, fire and domestic animals have been identified as threats to the species. Discussion of and details concerning the threats faced by *C. thwaitesii* and recommendations on reducing them are given in Chapter 8.

Genus: *Dasia* Gray, 1839.

***Dasia halianus* (Haly & Nevill, 1887).**

English: Haly's tree skink, Sinhala: Helige rukhiraluva. Status: Not endemic.

On 28 July 2005 an adult female early gravid (with SV - 86 mm and Tail – 57 mm, Axila - Groin - 45mm, weight - 17 grams) was observed around 11 am at the base of a large tree at Pitawala Patana (approximately 820 m above sea level). It was mortally injured, having probably been attacked by a bird (Plate 6 Figure 1) and had an unusual colouration which has not been recorded before. This was also the first time it has

been recorded in the wet zone and is the highest elevation at which this species has been found, as the few observations of this species have been from the Lowland Dry Zone (Das & de Silva, 2005). Another specimen was observed on the same day crossing the road around 12 noon at Illukkumbura Village. It quickly burrowed and disappeared into the loose soil (Plate 6 Figure 2). Another specimen in Tropical Mixed evergreen forest at Illukkumbura (638m) escaped under soil near a tree base and was never seen again. This species was sympatric with *Chalicidoseps thwaitesii, Cnemaspis* species, *Geckoella triedrus, Hypnale hypnale, Nessia bipes* and *Otocryptis weigmanii.* With both specimens immediate search by five persons could not locate them again.

Samarakoon (2004) reported another female *Dasia halianus* (total length 130 mm) falling from a *Terminalia arjuna* tree around 14.30 hours at Illukkumbura (along the Theligamu Oya). Our observations indicate that *Dasia halianus* exhibit arboreal, terrestrial as well as fossorial habits confirming Deraniyagala's (1953) observations made under captivity. Haly (1890) noted about *Lygosoma halianus* (now *Dasia*) that "the rarity of this species is accounted for by the fact that it lives on the tops of high trees", while Deraniyagala (1931) noted that a specimen was encountered at Dambulla "on a low mud wall near a pond" .

Genus: *Lankascincus* Greer, 1991.
The genus *Lankascincus* was recently described by Greer (1991), for six species of scincid lizards (*Lankascincus deignanai, L. deraniyagalae, L. gansi, L. fallax L. taprobanensis,* and *L.taylori*) that are endemic to Sri Lanka. The endemic *Lankascincus* represents a distinct lineage of the lygosomine scincid radiation (Austin *et al.*, 2004) and is the most common skink genus found on the island. Nonetheless, many aspects of its biology are poorly understood. Of the six known *Lankascincus* species, five were encountered in the Knuckles.

Lankascincus was often observed living sympatrically with *Chalcidoseps thwaitesii, Nessia bipes* and *Mabuya* species. Most gravid females that were observed had two eggs.

Another 267 further specimens were observed in the field but could not be caught or could not be keyed with the current literature (Greer, 1991), as the genus is currently under revision. During the Knuckles survey we collected one *Lankascincus* specimen which could not be identified using available keys. Presently molecular as well as alpha taxonomical work on this specimen is in progress.

***Lankascincus deraniyagalae* (Greer, 1991).**
English: Deraniyagala's Lanka skink, Sinhala: Daraniyagalage lakhiraluva. Status: Endemic.

Five specimens were observed in Illukkumbura (638m) in a Tropical Mixed Evergreen Forest under logs and leaf litter. The total length range of 6 specimens was 66 to 113mm with a weight range of 1.75 to 2.00 grams.
Lankascincus deraniyagalae (Plate 6 Figure 3) was found to be a rare skink in the Knuckles. Our observations constitute the first record from the Range, although the species is previously known from the Central hills and Galle District. Considered to be Endangered in the CAMP report, which assessed this reptile using IUCN Red List criteria B1+2bc , (de Silva *et al,* 2000) the species is also listed as Threatened in the 1999 National list of threatened animals (IUCN, Sri Lanka, 2000).

***Lankascincus fallax* (Peters, 1860).**
English: Common Lanka skink, Sinhala: Sulaba lakhiraluva. Status: Endemic.

118 specimens were observed in Pine Plantations, Riverine forest, Scrub Forest, Tropical Mixed Evergreen Forest and Upper Montane Forest in straw, inside termite mounds, leaf litter, on rock, root systems, under logs, under rocks and in human habitation. Specimens were found in Dawattagalla (1344m), Dehigolla (1122m), Elkaduwa (999m), Gammaduwa (1002m), Illukkumbura (476m), Kalupahana (924m),

Kandegama (750m), Karakolamana (162m), Kobonilagala (1379m), Laggala - Pallegama (571m), Lakegala (434m), Liyangolla (634m), Navanagala (1200m), Nitre cave (1065m), Pitawala (579m), Puwakpitiya (550m), Rambukoluwa (242m), Riverston (1212m), Sphinx rock (951m), Sulugune (170m) and Yahangala (300m). The total length range of 6 specimens was 66 to 113mm and the weight range was 1.75 to 2.00 g. Gravid females and hatchlings were observed during the study period.

Lankascincus fallax (Plate R6 Figure 4) was the most common skink in the Knuckles (in both degraded and natural habitats) and has been previously recorded from the Range (Ginge, 1994; Bambaradeniya and Ekanayake, 2003). The species is widely distributed throughout the island up to an elevation of 1050m. It is considered to be at Low risk in the CAMP report, which assessed this reptile using IUCN Red List criteria B1+2bc (de Silva *et al,* 2000).

***Lankascincus gansi* (Greer, 1991).**

English: Gans' Lanka skink, Sinhala: Gansge lakhiraluva. Status: Endemic.

Three specimens were observed in agricultural land and Lower Montane Rock Outcrop Forest under rocks at Bambugala (824m) and Lakegala (553m). The total length range of 2 specimens was 56 to 91 mm with a weight range of 1.25 to 1.50 g. Gravid females were observed in September.

Lankascincus gansi (Plate 6 Figure 4) were uncommon to rare skinks in the Knuckles but have been recorded from the Range at Pallegama. The species was previously found at elevations of 30-700m (Das & de Silva, 2005) and is considered to be Vulnerable in the CAMP report, which assessed this reptile using IUCN Red List criteria A1c (de Silva *et al,* 2000). It is also listed as Threatened in the 1999 National list of threatened animals (IUCN, Sri Lanka, 2000).

***Lankascincus taprobanensis* (Kelaart, 1854).**

English: Smooth Lanka skink, Sinhala: Sumudu lakhiraluva, Thel lakhiraluva. Status: Endemic.

18 specimens were observed in Riverine Forest, Lower Montane Forest, Tropical Mixed Evergreen Forest, Upper Montane Forest including monoculture plantations (e.g. cardamom) and in anthropological habitats. They were observed at Kobonilagala (1379m), Medamahanuwara (1033m), Dawattagalla (1344m), Riverston (1212m), Sphinx Rock (576m), Kandegama (750m), and in microhabitats of dead vegetation, leaf litter, under logs and under rocks or on the surface of the ground. The total length of 2 specimens ranged from 43 to 95mm with a weight range of 0.50 to 2.00 g. A gravid female and 4 hatchlings were observed during the study period.

Lankascincus taprobanensis

(Plate R6 Figure 5 and Plate 6 Figure 5) was encountered in a wider range in the Knuckles and has been recorded here before (Bambaradeniya and Ekanayake, 2003) but was nonetheless an uncommon skink in the area. Previously found at an elevation range of 1000 - 2300m in the Central Massif (Das & de Silva, 2005) and considered to be Endangered by the CAMP report, which assessed the reptile using IUCN Red List criteria B1+2bc (de Silva *et al,* 2000) the species is also listed as Threatened in the 1999 National list of threatened animals (IUCN, Sri Lanka, 2000).

***Lankascincus taylori* (Greer, 1991).**

English: Taylor's Lanka skink, Sinhala: Telorge lakhiraluva. Status: Endemic.

27 specimens were observed, found in Tropical Mixed Evergreen Forest, Lower Montane Forest, Riverine Forest and in monoculture plantations (e.g. Pine plantations), at Corbet's Gap (688m), Dumbanagala (1049m), Illukkumbura (429m), Kandegama (750m), Lakegala (434m), Pitawala (836m), Rambukoluwa (242m) and Yahangala (770m), under rocks, logs, leaf litter, and humus. The total length of 9 specimens ranged from 72 to 133mm with weights ranging from 0.50 to 2.50 g. Three Gravid females and hatchlings were observed in September.

Lankascincus taylori was the second most common skink in the Knuckles (in both

degraded and natural habitats) and has been previously recorded from the Range as well as in the Central Massif and Sinharaja area in montane forests at elevations ranging from 470-1350m (Das & de Silva, 2005). Considered to be Vulnerable in the CAMP report, which assessed this reptile using IUCN Red List criteria B1+2bc (de Silva *et al,* 2000) the species is also listed as Threatened in the 1999 National list of threatened animals (IUCN, Sri Lanka, 2000).

Genus: *Lygosoma*

***Lygosoma punctata* (Gmelin, 1799).**
English: Dotted skink, Sinhala: Tit hiraluhikanala. Status: Not endemic.

Twelve specimens of *Lygosoma punctata* (Plate R6 Figure 6) and (Plate 6 Figure 6) were observed in degraded open habitats such as abandoned chena cultivation, disturbed Lower Montane Forest and Scrubland, in Deanston (1250m), Kalupahana (862m), Kobonilla (1100m), Lakegala (553m) and Pitawala (836m), under rocks and under logs. The total length of 5 specimens ranged from 72 to 167mm with weights ranging from 8.00 to 9.00 g. Though they were more sub-fossorial in nature, on several occasions we observed juveniles (with red tails) basking on heated rocks during the day. Although found in numerous locations in the island, this is the first time it has been observed in the Knuckles. The species is widely distributed throughout India, Bangladesh and Pakistan.

***Lygosoma singha* (Taylor, 1950).**
English: Taylor's skink, Sinhala: Taylorge hiraluhikanala. Status: Endemic.
One male specimen (Plate 6 Figure 6 & Plate R6 Figure 7) was observed under a large stone in an Acacia Plantation in Deanston (1134m). The species had a total length of 157mm and a weight of 8.00 g. The CAMP report does not have sufficient data to classify the species, (de Silva *et al,* 2000) as does the 1999 National list of threatened animals (IUCN, Sri Lanka, 2000), which does not list the species as Threatened as it was doubted whether or not the species actually existed. This was the first time another specimen was found after the type was described by Deraniyagala (1953).
Genus: *Mabuya* Fitzinger, 1826.
Note:
In addition to the species *Mabuya* listed below, 57 more specimens were observed in the field which, either could not be caught and identified or, if caught could not be keyed with current literature.

***Mabuya beddomii* (Jerdon, 1870).**
English: Beddome's stripe skink, Sinhala: Vairan hikanala. Status: Not endemic.

Two specimens of *Mabuya beddomii* (Plate 6 Figure 7) were observed in Lower Montane Forest and Riverine Forest habitats in Elkaduwa (999m) and Puwakpitiya (519m) near tree root systems. The total length of 2 specimens ranged from 171 to 183 mm with weights ranging from 11.00 to 12.50 g. One of these was a Gravid female with 2 eggs. This species was not as commonly seen as *Mabuya macularia*. Like most *Mabuya* species, *M. beddomii* was quick to escape.

This is the first time it has been recorded in the Knuckles and is considered to be Threatened in the 1999 National list of threatened animals (IUCN, Sri Lanka, 2000).

***Mabuya carinata lankae* (Deraniyagala, 1953).**
English: Common skink, Sinhala: Sulaba hikanala. Status: unique at sub-species level.

Mabuya carinata lankae is the largest scincid lizard in the country. It is a common and widely distributed species although only 18 specimens were observed, this is because the study didn't sample degraded habitats in which it is most commonly found. It was found in Human agricultural areas and Riverine

Forest habitats, in Corbet's Gap (688m), Guruwela (211m), Hettipola (144m), Illukumbura (429m), Kalupahana (825m), Lakegala (580m), Liyangolla (634m), Pitawala (579m), Puwakpitiya (519m), Sphinx Rock (576m) and Yahangala (770m), in highly disturbed microhabitats under rocks, walls, on bare ground and in

leaf litter. The total length of 2 specimens ranged from 188 to 310mm with weights ranging from 13.0 to 14.00 g. One gravid female and a hatchling were observed during the study period. Previously recorded in the Knuckles the species is considered to be Low risk by the CAMP report, which assessed this reptile using IUCN Red List criteria (de Silva *et al,* 2000). It is not listed as a Threatened species in the 1999 National list of threatened animals (IUCN, Sri Lanka, 2000).

***Mabuya macularia maculara* (Blyth, 1853).**
English: Bronze-green little skink, Sinhala: Pingu hikanala. Status: Not endemic.

Mabuya macularia (Plate 6 Figure 8) was the most common *Mabuya* species observed in degraded habitats, although only 9 specimens were observed. This is because the study didn't sample degraded habitats in which it is most commonly found. Specimens were found basking on heated rock surfaces during the day and are commonly observed actively foraging on rock surfaces. They were observed in highly disturbed Lower Montane Forest, Riverine Forest, Tropical Mixed Evergreen Forest and Upper Montane Forest habitats in Deanston (1315m), Liyangolla (634m), Dotalugala (1131m), Lakegala (740m), Yahangala (300m), Bambugala (821m) and Kobonilagala (1325m). The total length of 3 specimens ranged from 99 to 175 mm with weights ranging from 9.50 to 13.00 g. Two gravid females, a hatchling and eggs laid under leaf litter were observed during the study period. The species has previously been recorded in the Knuckles. It is considered to be a Threatened species by the 1999 National list of threatened animals (IUCN, Sri Lanka, 2000).

Genus: *Nessia* Gray, 1839.
***Nessia bipes* (Smith, 1935).**
English: Smith's snakeskink, Sinhala: Smithge sarpahiraluva. Status: Endemic.

This species was found to be the dominant fossorial skink in the Knuckles where it is widely distributed in many parts, and of which an account is included in this publication (De Silva *et al.*, 2005j) (Plate 7 Figure 5). This species has been previously recorded in the Knuckles by Gans (1995) in Gammaduwa and is considered to be Endangered by the CAMP report, which assessed the reptile using IUCN Red List criteria B1+2bc (de Silva *et al,* 2000). The species is also listed as Threatened by the 1999 National list of threatened animals (IUCN, Sri Lanka, 2000).

***Nessia sarasinorum* (Müller, 1889).**
English: Sarasin's snakeskink, Sinhala: Sarasinge sarpahiraluva. Status: Endemic.

Five specimens of *Nessia sarasinorum* (Plate 7. Figure 6) were observed in one locality in the north east of the Knuckles. An account of this skink is included in this publication (De Silva *et al.*, 2005j) This species has not been previously recorded in the Knuckles and is considered to be at Low risk by the CAMP report, which assessed the reptile using IUCN Red List criteria (de Silva *et al,* 2000). It is not listed as a Threatened species in the 1999 National list of threatened animals (IUCN, Sri Lanka, 2000) although it is listed by Bambaradeniya (2001) as a Threatened species.

Plate R6 - Skinks

Figure 1 *Chalcidoseps thwaitesii* (male) ©SG

Figure 2 *C. thwaitesii* (female) ©SG

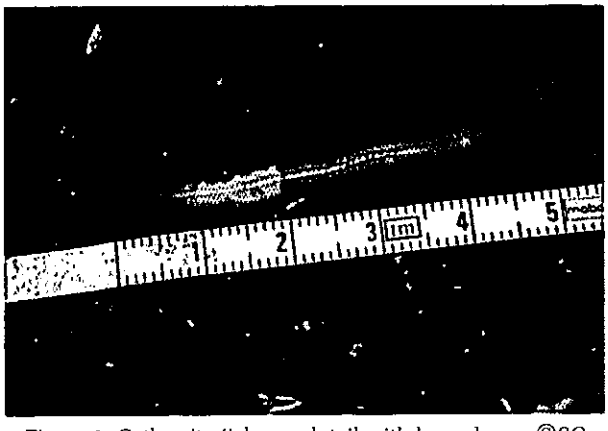


Figure 3 *C. thwaitesii* dropped tail with leucoderma ©SG

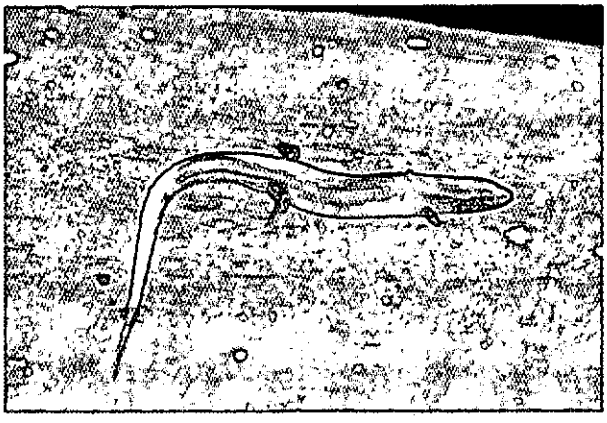


Figure 4 *Lankascincus fallax* (male) ©SG

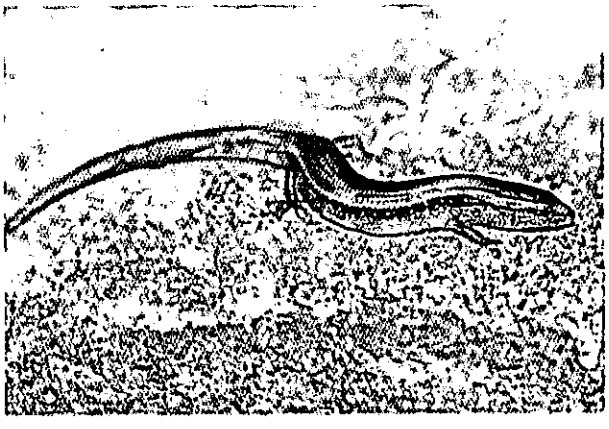


Figure 5 *Lankascincus taprobenensis* (male) ©SG

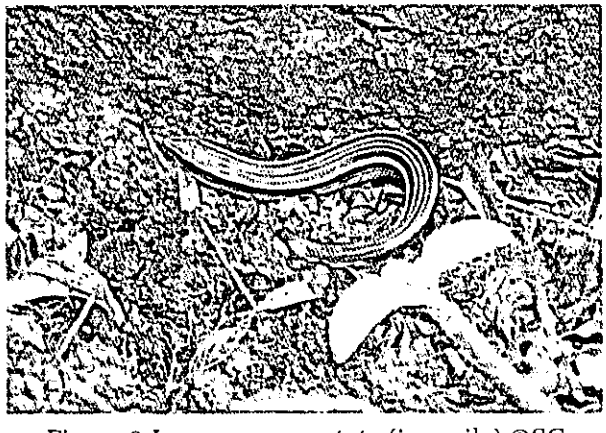


Figure 6 *Lygosoma punctata* (juvenile) ©SG

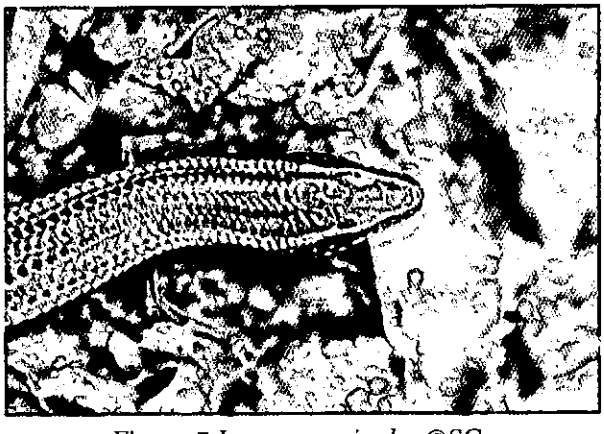


Figure 7 *Lygosoma singha* ©SG

Figure 8 Unidentified skink: Elkaduwa ©SG

Chapter 5
Geckos

Introduction

At present 25 species and sub-species of gecko are known from Sri Lanka. Fifteen of these are endemic (Batuwita & Bahir 2005; Deraniyagala 1953; de Silva 2001; Kluge 2001; Manamendra-Arachchi 1997; Smith 1935 and Taylor 1953). In addition to these, several new species of gecko have been discovered in recent times that await formal description. Following this Sri Lanka will have a high diversity of geckos, the majority of which will be endemic.

Given below is a list of geckos observed in the Knuckles Massif, together with some pertinent ecological notes. The status of, and threats to these geckos are also briefly discussed.

Genus: *Cyrtodactylus*, Gray, 1827.
***Cyrtodactylus soba* (Batuwita & Bahir, 2005).**
English: Dumbara Bent-toed Gecko, Sinhala: Dumbara maha kalae huna.
Status: Endemic.

Introduction

Cyrtodactylus soba, the recently described Dumbara Bent-toed Gecko is an endemic member of the family Gekkonidae. Despite being one of the largest of Sri Lanka's geckos, it evaded detection until recently due to it been mistakenly identitfied as the species *Cyrtodactylus frenatus*, to which it bears similar phenotypic characteristics (Batuwita & Bahir, 2005). Very little is known of the species' ecology and behaviour. Past research on the species has been general and limited to informal field recordings, when specimens were usually mistaken for members of the *C. frenatus* species.

Morphometry

During its study, Project Knuckles encountered 77 specimens of *C. soba*. Of these, 73 were adults/sub-adults and 4 were juveniles/hatchlings. Of all the specimens sampled 23 were male, 32 were female and 18 were unsexed, having escaped before a researcher was able to identify their gender.

Cyrtodactylus soba is a large gecko (Plate R7 Figures 1 & 3 and Plate 9 Figures 1 & 2). 8 male specimens observed had a mean snout to vent length of 93.1mm ± 19.1 SD. Male mean body mass was 19.6g ± 5.25 SD. 19 female specimens observed had a mean snout to vent length of 85.9mm ± 20.2 SD, with a mean body mass of 17.0g ± 7.9 SD. The snout to vent length of day old hatchlings ranged from 38 to 41 mm with tails measuring 40 mm. (Plate 9 Figure 3). For further discussion on morphology see De Silva *et al.*, (2005l).

Although the taxonomic description of *C. soba* by Batuwita and Bahir (2005), specified that *C. soba* had five pre-anal pores, some specimens were observed exhibiting a range of one to five pre-anal pores, although [illegible] was close to five.

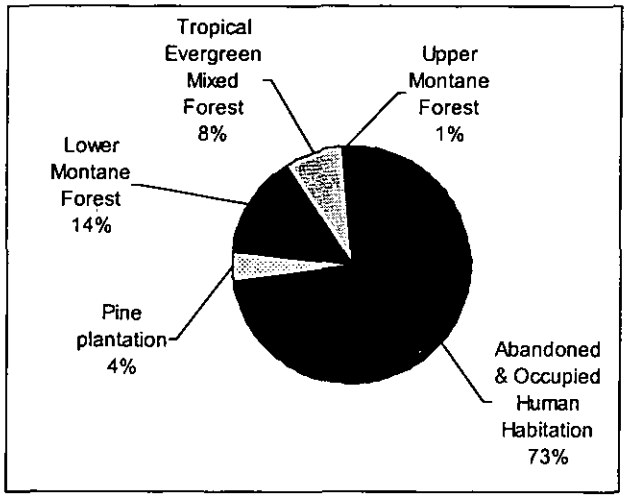
Habitat and distribution

Cyrtodactylus soba has been observed in and around the periphery of the Knuckles Conservation forest. The species was observed inhabiting an altitude range of 550 to 1550m above mean sea level in the localities of Allugalena (1000m), Corbet's Gap (1313m), Deanston (816m), Dehigola (1191m), Dotalugala (1550m), Dumbanigala (1132m), Hare Park (1315m), Kobonilagala (1458m), Kobonilla (1191m), Lakegala (705m), Loolwatte (1013m), Medamahanuwara (1033m), Nitre cave (550m), Pitawala (852m), Sphinx Rock (1313m) and Udadumbura (872m).

The study found the species less frequent in forest habitats. Instead, specimens were found in disturbed Lower Montane Forest (14%) and Upper Montane Forest (1%), usually in Cardamom cultivations. They were also found in pristine Tropical Evergreen Mixed Forest (8%). *C. soba* specimens were recorded inhabiting pine forests (4%), where they live in the split bark on the trunk of the trees. Here they are

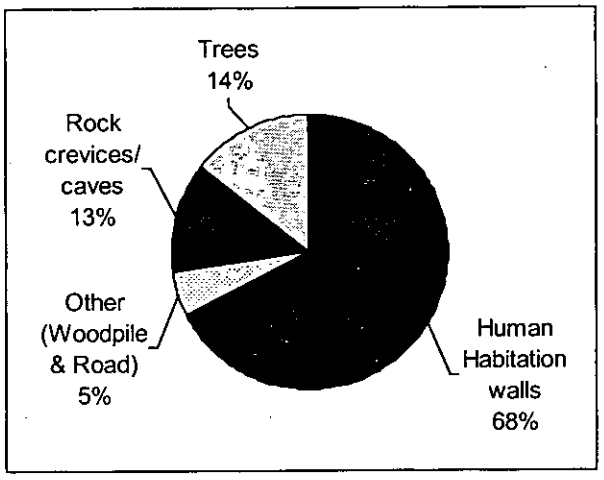
frequently found living sympatric to *Cnemaspis* species. Where forest cover has been cleared and replaced with human habitation and other anthropogenic land use types, the species continues to exist, indeed flourish (73%). Many can be seen in occupied and abandoned human habitation such as houses, sheds, and disused cardamom barns (Figure 1).

Figure 1
Distribution of *Cyrtodactylus soba* according to vegetation habitats



The majority were observed on wall of human habitation (68%), and 75% of these were occupied human habitations (barns, temples and tea factories). They were found behind picture frames; doors etc. probably due to their diet (see discussion below). Being arboreal, the species' natural habitat includes trees (14%) with loose dried bark and crevices (Plate R7 Figure 2) in which individuals rest during the day. They have also been observed inside crevices in large boulders and rock caves (13%). One specimen was also observed crossing a tarmac road (1.3%) at night in a pine plantation.

Figure 2
Microhabitat of *Cyrtodactylus soba* in the Knuckles ecosystem



Natural History

C. soba was found to be the dominant gecko species in the Knuckles. In areas of human habitation *C. soba* were observed living sympatrically, not only with humans, but also with a number of other geckos including *Geckoella triedrus, Hemidactylus depressus, Hemidactylus brookii parvimaculatus, Gehyra mutilata*, and a selection of *Cnemaspis* species.

As *C. soba* has been observed most frequently in houses, it was of interest to the project to ascertain why they chose such a habitat and how they reached it, as many houses found to contain *C. soba* were a considerable distance from any proper forest patches. As a case study, the project lodge was examined. Work began on the construction of the building in 2004, and at the time, no *C. soba* were present. On one occasion, workmen observed a *Geckoella triedrus*. During construction, the vegetation surrounding the premises was cleared. It was a number of months until *C. soba* arrived in the building, possibly the length of time it took for the individuals to migrate from the forest. At no point during construction or indeed for many years has there been a direct route in the form of forested area from the lodge to the nearest forest patch. Following the removal of scrub vegetation surrounding the lodge, there was a considerable reduction of possible predators such as rats (*Rattus rattus*) and snake species (*Ptyus, Dendrelaphis* and *Boiga* species), thus reducing important predators from the vicinity of the habitat occupied by *C. soba* which may have encouraged the population to establish itself.

Many colour variations of *C. soba* were observed. These variations reflect the specimen's microhabitat. Those recorded in buildings with white washed walls were considerably paler than those in wattle and daub buildings or those from the forest. Those found in rock crevices were often darker.

Of those sampled, 32 (41%) had regenerated tails. The mean length of these regenerated sections from 17 specimens was 55.9mm. Regenerated tail sections are identifiable by conspicuous changes in caudal scale pattern, colouration and colour pattern in relation to the rest of the specimen's body (Plate R7 Figure 3). Tail regeneration was observed both in specimens living in areas of human habitation and in forests.

The rate of sighting of specimens was significantly reduced in the wild. In their natural habitat, *C. soba* were observed inhabiting tree crevices and grooves in tree

trunks where they would wait during the day. On the route towards Lakegala they were observed only in very large trees, emerging and descending the tree at 7 pm. They would not descend lower than one or two meters above the ground. The diameter at breast height of 5 of these large trees ranged from 30 to 510cm. There was almost always one specimen per 2 trees sampled.

In the wild, they have been observed foraging on top of rocks and boulder systems during the night, although this was recorded only once, on the way to Lakegala from Narangamuwa village. *C. soba* is a nocturnal species, emerging to hunt around dusk. They will remain hunting until shortly before dawn, between 6:30 and 7 am before returning to a suitable spot in which to rest during the day. At night time inside human habitation, *C. soba* are seen at higher sections of the wall, therefore out of reach of humans. However, on outside walls they descend lower to feed, although they were not observed foraging around the base of the wall: this lower height is instead used by *Geckoella triedrus* to forage.

In human habitation, where *C. soba* were most commonly observed, they tend to spend the day hidden behind doors, furniture and household objects hanging on walls such as paintings, clocks, calendars, kitchen utensils and curtains. Competition for a daytime location is high. In general, the individual who returns to a microhabitat first holds occupancy over it, although some of the larger males were willing and able to contest this right, driving out the previous occupant using aggressive tactics. Those who have secured good refuges hold out for the whole day until the evening when they return to the roof. Those without good refuges end up in marginal places, such as behind curtains, where they are not well hidden. The species exhibits highly territorial behaviour inside houses. In addition to daytime shelter, there is further competition for feeding grounds in the evening. A number of observations were made on male-to-male and male to female territorial competitive encounters. Male to female confrontations were observed to be less common than male-to-male confrontations. These confrontations involve face to face staring behaviour, which was observed on occasion to last for several hours. Adult males would arch their bodies, raise their heads and curve their tails. If one individual backs down, a chase may ensue, with the victor biting the loser and driving it away. Inside human habitation, the victor would often force the loser to jump from the wall onto the ground.

These conflicts could be a sign of overcrowding and lack of suitable refuges inside houses. On account of the usage of artificial light, there is plenty of insect prey available during the evening, although even abandoned houses, cardamom barns and warehouses with no lights were also found to have high numbers of *C. soba* present at Dotalugala, Kobonilla, Dehigolla, on the Allugalena Cave trail and in Pitchlandwatte bungalow by Rangala road near Corbet's Gap.

Only on one occasion has a *C. soba* been seen foraging during daytime. This occurred at Kahatagola, on a rock surrounded by water, suggesting that the specimen swam there. A second *C. soba* was then observed swimming in the same location shortly after. The species appears to show a general swimming aptitude, although they appear to grow tired after a few minutes. As there are plenty of invertebrates, mainly arthropods, on the water surface in small ponds it would certainly be feasible for *C. soba* to gather sufficient food in such a locality.

When aggravated, *C. soba* were observed utilising a caudal lure mechanism. This is believed to be a distraction tactic. In the case of an encounter with a possible predator, the caudal lure would divert attention to the tail, which, if detached, could afford the *C. soba* a chance to escape. Although thought to be slow movers, *C. soba* can move rapidly when agitated in order to avoid capture. When caught, some males were observed to invert their penis as a response. The reason behind this is not clear. Of 23 males caught, 3 (13%) inverted their penis upon capture.

Furthermore, of the 74 specimens caught a number of responses on capture were observed, such as struggling (73%), biting (26%), defecating (36%), lure (15%), emitting a distress cry (12%), feigning death (5%%) and autotomising the tail (8%). Autotomised tails, despite being an important source of protein are not re-eaten by the individual who has autotomised. They are left alone, even if the specimen remains very close to the lost tail section. Those who have lost tails become less active. Following an autotomy one individual did not move from his refuge for four days, even during the night. In addition to autotomising tails, *C. soba* has been observed shedding its skin but, unlike lost tails, a specimen was observed in one instance to eat its shed skin.

Extensive studies were conducted on the *C. soba* population inhabiting the team's lodge. When the lodge was uninhabited for three to four days, *C. soba* were found to remain active during the daytime and would only seek shelter with the return of humans to the building. It was documented that when the building was unoccupied for longer, the housekeeper encountered up to four or five tails lying on the ground per week. This either suggests that competitive behaviour is more readily displayed by *C. soba* when they are not disturbed by human presence, and that in the absence of humans, individuals are more willing to contest feeding and resting locations, or it suggests some other external influence. It is possible that in the absence of humans, predation by other animals increases. On one occasion two *C. soba* were observed fighting with a rat on the roof rafters. All three emitted distress cries, before the rat fled. The incident lasted only a few minutes. It is possible that rats enter the premises more frequently when it is free of humans.

Since many autotomised tails had been observed in the lodge during a period of human absence, it would suggest that there were many more *C. soba* inhabiting the lodge than was immediately evident. Those recorded could only be a small proportion of the real population living on the premises. A mark and recapture study is necessary to determine the actual population inhabiting the building, and if large numbers are revealed in one lodge, it is feasible that similar numbers exist in other buildings around the Knuckles forest.

C. soba were observed climbing through holes in the roof via ceiling rafters. They were also observed on the walls on the outside of the building. In 2004, two specimens were observed climbing from the roof of a building to an adjacent tree. This movement from building to tree is believed to be severely restricted if the adjacent trees are too far away. Specimens were not observed travelling from building to tree on any other occasion although they were observed jumping from branch to branch of several trees.

Two territorial incidents were observed in the project lodge in 2005, the first on the 11th August at six thirty in the evening, and the second on the 15th August at approximately 6 o'clock in the morning. The encounter was between two males on the inside walls of the building. The first encounter resulted in the smaller male being chased away. He emitted a distress cry but escaped being bitten. During the second encounter the two males assumed a typical confrontation posture for some time. The larger specimen adopted a caudal lure and opened its mouth. It then chased the smaller individual, forcing him to jump off the wall. Once on the floor, the specimen attempted to climb back but as the lower levels of the walls are tiled, it could not do so. To climb, *C. soba* utilise their claws. They do not possess sticky pads that enable some geckos to climb a tiled surface. Two individuals were also observed fighting on the morning of the 12th of August 2005, on the crossbars of the roof. The victor chased the loser across the bar where it defecated onto the beds below.

Thermoregulation

The mean body temperature and associated environmental temperatures in 18 *C. soba* were recorded. The maximum body temperature recorded was 32.7°C and the

minimum 17.9°C. Means with standard deviations were; body temperature = 23.8° ±3.5°, air = 23.3° ±2.6°, substrate = 23.7° ±4.9°. A two-sample *t*-test indicated no differences between body and substrate or air temperatures; against air temp $p = 0.63$ and against substrate temp $p = 0.91$. There was also no significant departures in body temperature variance from variance in environmental temperatures, against air temperature $F = 1.81$, $p = 0.29$ and against substrate temperature $F = 0.51$, $p = 0.23$. These preliminary results suggest the geckos are thermoconformers, and do not attempt to actively control their body temperature.

Food

There does not appear to be any shortage of food for *C. soba* in households. From a building of four rooms, approximately ten droppings were found each morning from the previous night. As these were found in the centre of each room, it would suggest that the geckos spend a large portion of the night on the roof, most probably foraging for food, which would thus appear fairly abundant.

Faecal samples suggest that the *C. soba* diet is mainly comprised of large insects. Some observers in Kobonilla saw *C. soba* specimens feeding on grasshoppers. However, upon further examination of faecal samples it was discovered that the species has a wide range of prey.

Reproduction

No hatchlings were observed in the wild. Four juveniles were observed inside human habitation. In 2004, two eggs kept for ex-situ observation hatched under the supervision of Anslem de Silva. Hatchlings are clearly identified by their tails, which are pure white and almost luminous.

In addition, 4 clutches of eggs, identified as belonging to *C. soba*, were found inside logs, wood piles, on an abandoned habitation wall (Plate 9 Figure 5) and in leaf litter. On average these eggs were 19mm long and 12mm wide (Plate 9 Figure 4).

Of the 32 female specimens observed, 15 (47%) were gravid and were observed during the months of July and August. The average number of eggs present in a gravid female was 2.

Parasites

Specimens observed in both pristine and disturbed habitats, was found to be infested with red mites, a recognised gecko ectoparasite, commonly found on many exotic, wild and domestic geckos Miller (2006). Of the specimens recorded 16 (21%) had (up to nine) mites attached to a part of their body. The most common locations of the body to which these mites were attached were inside the eyelid, around the eye and around the axilla. It was not determined whether the mites belong to the genus *Geckobia* (Family: Pterygosomatidae) or chigger mites (larvae of Trombiculid mites), which is also a recognised ectoparasite in the skin folds and creases on many reptiles. For internal parasites see De Silva *et al.*, (2005p).

Threats and status

As it is a newly described species, its IUCN endangered status is yet to be determined . However, during the period when *C. soba* was believed to form a part of the *C. frenatus* population, the species was classified as Vulnerable under criteria A2c, B1 and 2bc. The classification for *C. soba* is almost certain to change, on account to the species' somewhat smaller population. Although thought to be endangered, *C. soba* are locally common in the Knuckles. It is merely their small area of occupancy that poses a threat to their future survival. Whilst the generation time of the species is estimated to last roughly 5 to 7 years, actual population numbers remain unknown.

During the survey, the species was found in human habitation with minimal search effort, suggesting that population densities are substantial, at least in those areas of the Knuckles ecosystem surveyed. Loss of natural habitats, application of agro-chemicals in natural habitats, fire, domestic animals (such as rats, cats) and other opportunistic animals (such as Coucals and Civets)'unfounded beliefs and subsequent wanton killings have been identified as

threats to the species. For discussion of these threats and further recommendations see Chapter 10.

Other Geckos observed in the Knuckles

The study only targeted *C. soba* as it is restricted to the Knuckles Range and it is believed that it should be listed in the IUCN Red List of threatened animals for Sri Lanka (as is *C. frenatus).* As most Sri Lankan geckos are considered to be threatened (Bambaradeniya, 2001; Wickramasinghe & Somaweera, 2002) observations were also made on other species, which allowed us to assess the gecko diversity of the Knuckles.

Table 1
Geckos Inhabiting the Knuckles ecosystem and Sri Lanka

Genus	Number in Sri Lanka	Number endemic	Number observed in Knuckles
Calodactylodes	1	1 (100%)	Nil
Cnemaspis	4	3 (75%)	4
Cosymbotus *	1	Nil	Nil
Cyrtodactylus	6	6 (100%)	1
Geckoella	3	2 (66%)	1
Gehyra	1	Nil	1
Hemidactylus	7	3 (43%)	5
Hemiphyllodactylus	1	Nil	Nil
Lepidodactylus	1	Nil	Nil
Total	25	15	12

* **NOTE**: Carranza & Arnold, 2006 have placed *Cosymbotus platyurus* within *Hemidactylus*.

Genus: *Cnemaspis*, Strauch, 1887.

***Cnemaspis kandiana* (Kelaart, 1853 "1852").**

English: Kandyan Day gecko, Sinhala: Kandukara divasarihuna. Status: Endemic.

Thirty specimens were found widely distributed in the Knuckles in acacia plantations, pine plantations, Lower Montane Forest, Riverine Forest and Tropical Mixed

Evergreen Forest habitats at Deanston (1122m), Dehigolla (1155m), Dumbanagala (1049m), Elkaduwa (748m), Gammaduwa (1002m), Illukkumbura (476m), Kandegama (750m), Lakegala (434m), Medamahanuwara (1033m), Navanagala (1200m), Puwakpitiya (519m) and Rajagala (1082m). They were found inside logs, leaf litter, rock crevices, on walls, tree bases and under rocks. One gravid female was observed during the study period, measuring 65mm in total length.

The air temperature in the locality was 30.2°C while the substrate temperature was 28.2 °C.

Cnemaspis kandiana was a common gecko in the Knuckles and has previously been recorded from the range (Ginge, 1994; Bambaradeniya and Ekanayake, 2003). It is known to be widespread throughout the Central Massif (Das & de Silva, 2005) but is considered to be Vulnerable in the CAMP report, which assessed this reptile using IUCN Red List criteria A1c (de Silva *et al,* 2000) but it is not listed as Threatened in the 1999 National list of threatened animals (IUCN, Sri Lanka, 2000).

***Cnemaspis jerdonii scalpensis* (Ferguson, 1877)**
English: Jerdon's Day gecko, Sinhala: Jerdonge divasarihuna. Status: Endemic.

There is some confusion over which literature refers to this species. For the purposes of this paper it is listed as *Cnemaspis jerdonii scalpensis,* (Plate 8. Figure 1) see discussion in De Silva *et al.*, (2005k). 24 specimens were observed in abandoned human habitations, Lower Montane Forest, Lower Montane Rock Outcrop Forest, Tropical Mixed Evergreen Forest and Upper Montane Forest, in Bambugala (824m), Dumbanagala (1132m), Emmaduwa (567m), Gammaduwa (1002m), Illukkumbura (638m), Kobonilagala (1325m), Lakegala (553m) and Pitawala (1162m) inside logs, leaf litter and abandoned walls, under corrugated iron sheets, tree bases, under bark, under logs and under rocks. At some localities colonies of up to 9 individuals were observed in one place (such as in Pitawala). *C. jerdonii scalpensis* is a comparatively large member of the Cnemaspis genus. The total length of 6 specimens ranged from 70 to 85mm with weights ranging from 1 to 2g. Two gravid females observed in September had red mites on their body. In localities where specimens were observed, air temperature ranged from 21.8 to 26.3°C while substrate temperatures ranged from 21.0 to 25.9°C. Microhabitat relative humidity ranged from 43 to 67%.

C. jerdonii scalpensis was an uncommon gecko in the Knuckles. It has been recorded from the range in Gammaduwa (de Silva *et al,* 2000; Wickramasinghe and Somaweera, 2005) and is known to be widespread throughout the island, where it is more common in the Dry and intermediate Zones than in the Wet Zone (Das & de Silva, 2005; Wickramasinghe and Somaweera, 2005). Considered to be Vulnerable in the CAMP report, which assessed this reptile using IUCN Red List criteria B1 + 2 bc , (de Silva *et al,* 2000) it is also listed as Threatened in the 1999 National list of threatened animals (IUCN, Sri Lanka, 2000).

***Cnemaspis podihuna* (Deraniyagala, 1944).**
English: Dwarf Day gecko, Sinhala: Kuda divasarihuna, Podi galhuna. Status: Endemic.

One specimen of *Cnemaspis podihuna* (Plate 8, Figure 2) was encountered in the Knuckles at Yahangala (313m), near Devearithanna Oya. The air temperature in the locality where it was observed was 30.6°C whilst the relative humidity was 40%. The specimen was observed 5 metres above the ground in an unknown forest tree with a girth at breast height of 200cm in a Tropical Mixed Evergreen Forest (Plate 8 Figure 4). It weighed 0.36g. It was sympatric to ants, a gecko egg – 180cm away with a substrate temperature of 29.0°C and another unidentifiable egg nearby with a substrate temperature of 30.7°C weighing 0.05g.

Cnemaspis podihuna can be considered very rare in the Knuckles, indeed it is known to be of restricted distribution throughout the island, although the species has previously been recorded from the range (Bambaradeniya and Ekanayake, 2003; Wickramasinghe and Somaweera, 2005). Considered to be the only Critically Endangered gecko in the CAMP report, which assessed this reptile using IUCN Red List criteria B1+2bc (de Silva *et al,* 2000) this is also the only species of gecko listed as 'Highly threatened' in the 1999 IUCN list of Threatened Fauna and Flora of Sri Lanka (IUCN, Sri Lanka, 2000).

***Cnemaspis tropidogaster* (Boulenger, 1885).**
English: Rough-belly Day gecko, Sinhala: Ralodara divasarihuna. Status: Not endemic.

27 specimens of *Cnemaspis tropidogaster* were observed, in pine plantations, Riverine Forest and Tropical Mixed Evergreen Forest habitats at Allugalena (1000m), Corbet's Gap (1313m), Dawattagalla (1344m) Deanston (1130m), Elkaduwa (1225m), Hunnasgiriya (931m), Lakegala (553m), Medamahanuwara (1033m), Meemure (600m), Pitawala (926m) and Yahangala (300m). Specimens were observed inside logs, rock crevices, on the walls of abandoned buildings, amongst root systems, on tree bases and under rocks. Although no females were found to be

gravid, one juvenile was observed during the study period, with a total length of 58mm and a weight of 1g. The microhabitat of 3 individuals had an air temperature range of 23.4 to 25.2°C and a substrate temperature range of 22.2 to 23.8°C.

Cnemaspis tropidogaster was a common gecko in the Knuckles and has been previously recorded from the range (Ginge, 1994; de Silva *et al,* 2000). It is known to be widespread in the Central, Sabaragamuwa and Eastern provinces (Das & de Silva, 2005). Considered to be Vulnerable by the CAMP report, which assessed this reptile using IUCN Red List criteria B1+2bc, (de Silva *et al,* 2000) the species is also listed as Threatened in the 1999 National list of threatened animals (IUCN, Sri Lanka, 2000).

***Cnemaspis:* unidentified species**

A *Cnemaspis* specimen with an enlarged central sub-caudal row (Plate 8. Figure 3) was encountered which could not be identified using the available keys. Molecular and alpha taxonomic investigation is currently underway to ascertain whether or not this could be a new species. Three specimens were observed in Lower Montane Rock Outcrop Forest at Bambugala (824m), on rock faces and under rocks. Two of the observed specimens were gravid females. The total length of 3 individuals ranged from 72 to 79mm with a mean weight of 1.5g. The air temperature in the microhabitats of individuals ranged from 24.9 to 26.2°C and substrate temperatures ranged from 23.3 to 26.9°C. The microhabitat relative humidity ranged from 29 to 53%.

General Notes on Reproductive Habits of *Cnemaspis*

As regards reproductive habits, over 50 gravid female specimens of *Cnemaspis* were recorded during the Knuckles expeditions of 2004 and 2005. All these females contained two eggs each. Communal as well as individual egg laying patterns were observed:

a) Large clusters of 50 to over 100 eggs were observed, usually on a rock surface and mostly inside rock caves (Plate 8 Figure 6). Some of these were the largest *Cnemaspis* egg clusters observed in the country.

b) Smaller clusters with 10 – 25 eggs were observed on rock surfaces inside caves and under rock flakes that were well protected from rain and the sun.

c) *Cnemaspis* eggs were observed as individual pairs attached to rock surface, tree trunks, inside crevices in house walls, on terracing, in leaf litter, under rock flakes, and inside rock caves.

Table 2
Some egg dimensions of *Cnemaspis* species inhabiting the Knuckles ecosystem

Weight	Width	Length
0.1g	5.5mm	6.5mm
0.1g	5.7mm	5.6mm
0.1g	5.7mm	5.6mm

NOTE: Similar findings have been observed in the ongoing island-wide gecko survey (A. Bauer & A. de Silva, 2003-2005).

Parasites
Internal parasites (coccidian oocysts) were observed in some *Cnemaspis* specimens, (refer De Silva *et al.*, (2005p).

Genus: *Geckoella*, Gray 1867.
***Geckoella triedrus* (Günther, 1864).**
English: Spotted Bow Finger gecko, Sinhala: Pulli vakaniyahuna. Status: Endemic.

Geckoella triedrus (Plate R7 Figure 5 & Plate 8 Figure 7) was the only largely terrestrial gecko observed in the Knuckles during the study. It is a slow moving, nocturnal gecko of medium size. Ninety-five specimens were observed during the study, 26 were female, 20 male, 33 were unsexed adults and 17 were juvenile or hatchlings. Specimens were mostly found to inhabit acacia plantations, pine plantations, abandoned chena agriculture, Lower Montane Forest, Tropical Mixed Evergreen Forest and Upper Montane Forest in Bambugala (821m), Corbet's Gap (1300m), Deanston (1094m), Dehigolla (1157m), Dickpatana (754m), Dotalugala (1092m), Elkaduwa (999m), Horakanda (1315m), Hunnasgiriya (1227m), Illukkumbura (638m), Kalupahana (1002m), Kandegama (742m), Kobonilagala (1059m), Kobonilla (1191m), Lakegala (553m), Loolwatte (1191m), Maningala (754m), Medamahanuwara (1033m), Pitawala (749m), Puwakpitiya (550m), Rajagala (1082m) and Yahangala (770m).

Individuals were found resting during the day, primarily under rocks, but also in human habitation, inside or under logs, amongst leaf litter and root systems, in tree holes and under bark. The total length of 21 adults ranged from 70 to 116 mm with weights ranging from 2.0 to 9.0g. The total length of 12 juveniles/hatchlings ranged from 45 to 61 mm while weights ranged from 0.5 to 2.0g. The air temperature in the microhabitats of 34 specimens ranged from 20.7 to 32.1° C whilst the substrate temperature ranged from 18.6 to 31.0° C. The relative humidity in 34 microhabitats of this species ranged from 28 to 92%. Thirteen gravid females were observed during the expedition period (June to September). All the gravid females examined had two eggs. A few hatchlings measuring 25mm from snout to vent and had 20mm tails too were observed. Some also had a visible umbilical opening. Two morphological variants of this species were found in the Knuckles and molecular and alpha taxonomy studies are in progress. A detailed account of *Geckoella triedrus* is in preparation (de Silva *et al.*, 2006 accepted for publication in Gekko).

Geckoella triedrus was a common gecko in the Knuckles and has previously been recorded from the range (Ginige, 1994; de Silva *et al*, 2000; Bambaradeniya and Ekanayake, 2003) as well as from the Central, Western, Sabaragamuwa and Uva provinces (Wickramasinghe and Somaweera, 2005). Considered to be Vulnerable in the CAMP report, which assessed this reptile using IUCN Red List criteria A1c, B1 and 2bc (de Silva *et al*, 2000) this species is also listed as Threatened in the 1999 National list of threatened animals (IUCN, Sri Lanka, 2000).

Genus: *Gehyra*, Gray, 1834
***Gehyra mutilata* (Wiegmann, 1834)**
English: Four-claw gecko, Sinhala: Caturanguli huna. Status: Not endemic.

This is a common house gecko in other parts of the country but in the Knuckles only a few were observed, in lowland human habitations at Illukkumbura and Laggala-Pallegama. It is possible that this species is more common in human habitations, but was not frequently encountered because sampling was not targeted at human habitations in the lowland areas of the region.

Genus: *Hemidactylus*, Cuvier, 1820.
***Hemidactylus brookii parvimaculatus* (Deraniyagala, 1953).**
English: Spotted House gecko, Sinhala: Pulli gehuna. Status: Endemic.

This is another common house gecko widely distributed in other parts of the country. In the Knuckles 4 specimens were documented in detail, inhabiting Tropical Mixed Evergreen Forest in Guruwela (211m), Illukkumbura (722m) and Pitawala (933m) on outside walls in abandoned buildings, in tree holes and under rocks. The total length

of 3 adults ranged from 95 to 114mm with all 3 weighing 1.5g. The air temperature of the specimen's microhabitats ranged from 25.4 to 26.4°C and substrate temperatures ranged from 26.0 to 28.1°C. Unusual colour patterns were observed (Plate R7 Figure 6). It is possible that this species is more common in human habitations, but was not encountered because sampling was not targeted at human habitations in the lowland areas of the region. On one occasion canabalism was observed on the wall of the hotel the researchers stayed in where one adult *Hemidactylus brookii* attacked and ate another subadult (de Silva *et al,* 2005m).
The species has previously been recorded from the range (Wickramasinghe and Somaweera, 2005) and is the only endemic Sri Lankan gecko whose populations are not considered to be threatened. It is not listed in the 1999 IUCN list of Threatened Fauna and Flora of Sri Lanka (IUCN, Sri Lanka, 2000). The species is considered to be at Low Risk in the CAMP report, which assessed this reptile using IUCN Red List criteria B1 and 2bc (de Silva *et al,* 2000). This may be due to the species' ability to adapt to man-modified environments and also because of its broad habitat and climatic condition tolerance (Wickramasinghe and Somaweera, 2005).

***Hemidactylus depressus* (Gray, 1842).**
English: Kandyan gecko, Sinhala: Hali gehuna. Status: Endemic.

Hemidactylus depressus was observed at several locations in the Knuckles. Around fifty specimens were observed, of which 23 specimens were documented in detail. They were observed in human habitation, Kandyan home gardens, Lower Montane Forest, Riverine Forest and Tropical Evergreen Mixed Forest at Corbet's Gap (688m), Illukkumbura (476m), Kobonilla (1191m), Lakegala (705m), Nugagolla (113m), Pitawala (579m), Puwakpitiya (622m) and Rambukoluwa (242m). Specimens were found inhabiting cave roofs, live and dead trees, leaf litter, low vegetation, rock faces, outside walls, under bark, under logs and under rocks. The total length of eight adults ranged from 110 to 154mm and weights ranged from 4.0 to 10.0g. The air temperature in the microhabitats ranged from 19.6 to 34.2°C and microhabitat substrate temperatures ranged from 24.6 to 33.3°C. One specimen was found with a red mite near its eye. Two specimens were gravid females and one specimen was a juvenile. An egg (11mm in length) was collected in August; it hatched on the morning of September 28th, 2004. The opening was approximately 9 x 9mm. The snout to vent measurement of the hatchling was 26mm and tail was 28mm. Half of the specimens encountered had regenerated tails. Whilst primarily nocturnal, a few specimens were observed to be active during the day.

The species has previously been recorded from the range (Ginige, 1994; Bambaradeniya and Ekanayake, 2003; Wickramasinghe and Somaweera, 2005). The species is listed as threatened in the 1999 IUCN list of Threatened Fauna and Flora of Sri Lanka (IUCN, Sri Lanka, 2000) and is considered to be at Low risk in the CAMP report, which assessed this reptile using IUCN Red List criteria B1 and 2bc (de Silva *et al,* 2000).

***Hemidactylus frenatus* (Schlegel, 1836)**
English: Common House gecko, Sinhala: Sulaba gehuna. Status: Not Endemic.

This is a common house gecko, widely distributed throughout Sri Lanka, but only a few specimens were observed in the Knuckles. Of the 7 specimens recorded, all were found inhabiting Dry Zone Agriculture, Human Habitation and Tropical Mixed Evergreen Forest in Hettipola (181m), Lakegala (740m) and Loolwatte (1013m). Specimens were found inside walls and under rock ledges, logs and rocks. The total length of 2 adults ranged from 91 to 96mm with weights ranging from 1.5 to 2.0g. The air temperature in the microhabitats of recorded specimens ranged from 29.8 to 35.0°C and substrate temperatures ranged from 33.3 to 35.4°C. It is possible that this species is more common in human habitations, but was not encountered because human habitations in the lowland areas of the region were not targeted in the study.

The species has previously been recorded from the range (Ginige, 1994; Bambaradeniya and Ekanayake, 2003). It is not listed as threatened in the 1999 IUCN list of Threatened Fauna and Flora of Sri Lanka (IUCN, Sri Lanka, 2000), as it is considered to be an introduced species found widely throughout South East Asia (Das & de Silva, 2005).

***Hemidactylus leschenaultii* (Duméril & Bibron, 1836).**
English: Bark or Sycamore gecko, Sinhala: Kimbul huna = crocodile gecko, Gas huna = tree or Kumbuk huna as it is frequently found on the Kumbuk tree (*Terminalia arjuna)*. Status: Not Endemic.

This is a common house gecko (Plate R7 Figure 7) widely distributed in the Dry Zone lowlands of the country. In the Knuckles only 2 specimens were observed; in abandoned agriculture and in human habitation at Hettipola (181m) and Liyangolla (113m) on a rooftop and on an outside wall. The total length of one adult was 123mm and its weight, 10g. Its microhabitat air temperature was 28.4°C and its substrate temperature was 28.3°C. This is a large, smooth-skinned gecko, which is primarily nocturnal although it was once observed to be active during the day. It is possible that this species is more common in human habitations, but was not frequently encountered because human habitations in the lowland areas of the region were not extensively sampled.

The species has previously been recorded from the range (Ginige, 1994; Bambaradeniya and Ekanayake, 2003). It is not listed as threatened in the 1999 IUCN list of Threatened Fauna and Flora of Sri Lanka (IUCN, Sri Lanka, 2000), as it is found widely throughout South Asia (Das & de Silva, 2005).

***Hemidactylus triedrus lankae* (Deraniyagala, 1953).**
English: Termite Hill gecko, Sinhala: Humbas huna. Status: Endemic.

This is a common gecko (Plate 8 .Figure 8 & Plate R7 .Figure 8) that is widely distributed in the Dry Zone lowlands of the country. In the Knuckles only 4 specimens were observed at night, in Kandyan Home Gardens and Tropical Mixed Evergreen forests at Illukkumbura (198m), Nugagolla (113m) and Pitawala (836m) on the road and on termite mounds. The total length of 2 adults ranged from 151 to 158mm with weights ranging from 10.0 to 11.0g. The microhabitat air temperature of these 2 specimens ranged from 29.5 to 32.0°C whilst the substrate temperature ranged from 29.0 to 30.2°C. One juvenile was observed during the study period.

The species has previously been recorded from the range (Ginige, 1994; Bambaradeniya and Ekanayake, 2003). It is considered to be at Low risk in the CAMP report, which assessed the reptile using IUCN Red List criteria (de Silva *et al,* 2000). It is not listed as Threatened in the 1999 National list of threatened animals (IUCN, Sri Lanka, 2000), as it is considered very common (Wickramasinghe and Somaweera, 2005).

Genus *Hemiphyllodactylus* (Bleeker, 1860).
***Hemiphyllodactylus typus* (Bleeker, 1860).**
English: Slender or Oceanic Worm gecko, Sinhala: Sihin huna. Status: Not Endemic.

Although not encountered in the study, this species has been observed in Kalupahana by Ginige (1994). This species is considered to be a unisexual and parthenogenic species now found throughout Asia.

Plate R7 - Geckoes

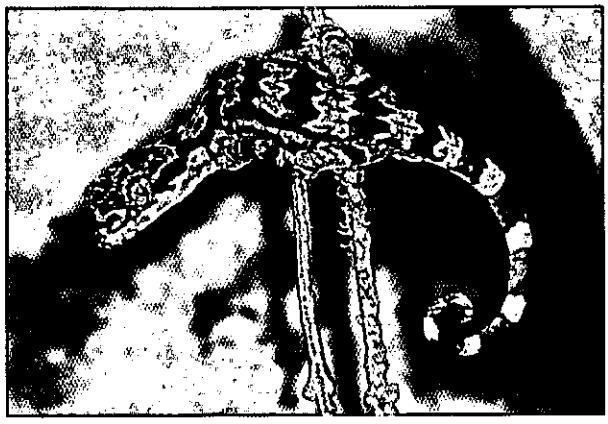


Figure 1 *Cyrtodactylus soba* (female) ©LP

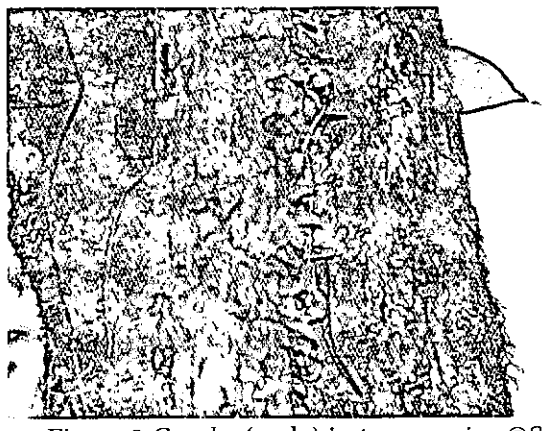


Figure 2 *C. soba* (male) in tree crevice ©SG

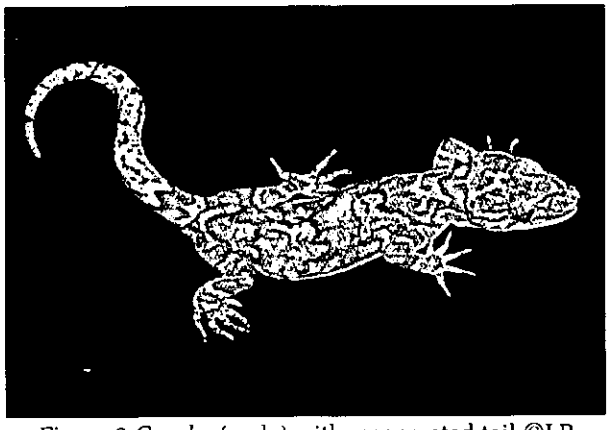


Figure 3 *C. soba* (male) with regenerated tail ©LP

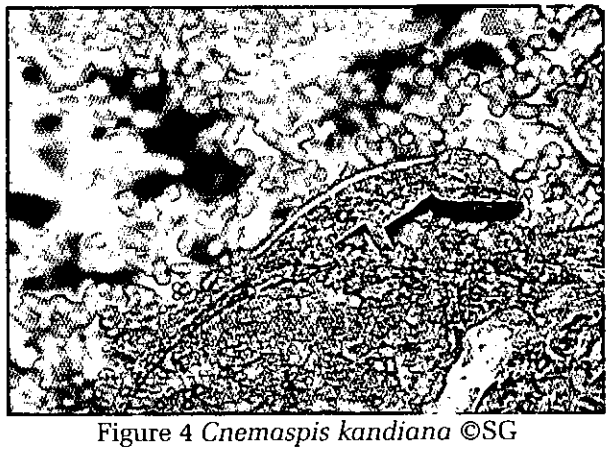


Figure 4 *Cnemaspis kandiana* ©SG

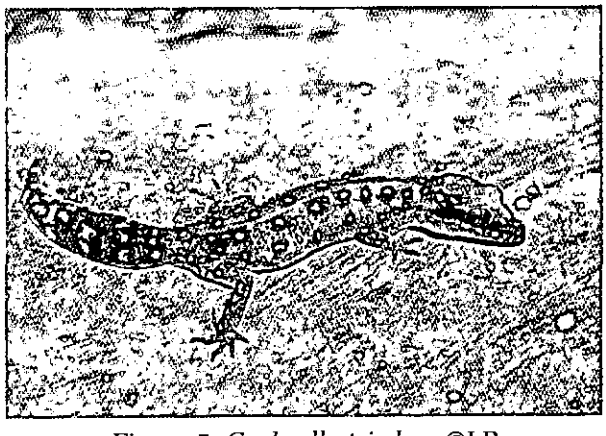


Figure 5 *Geckoella triedrus* ©LP

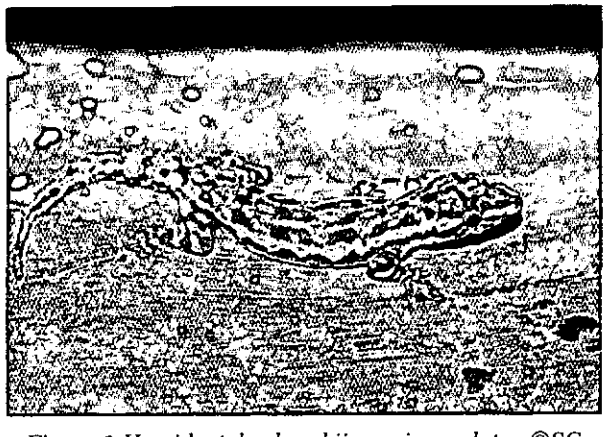


Figure 6 *Hemidactylus brookii parvimaculatus* ©SG

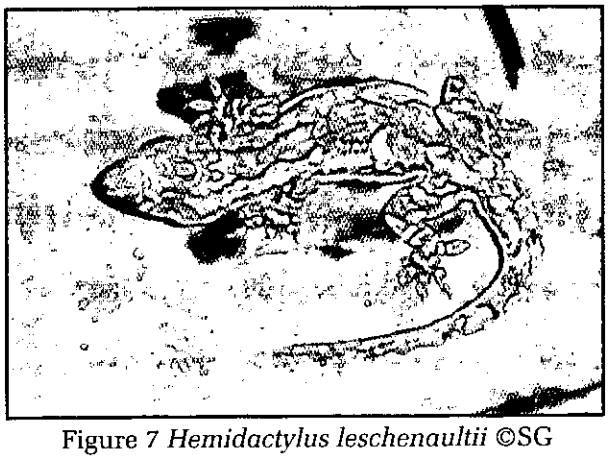


Figure 7 *Hemidactylus leschenaultii* ©SG

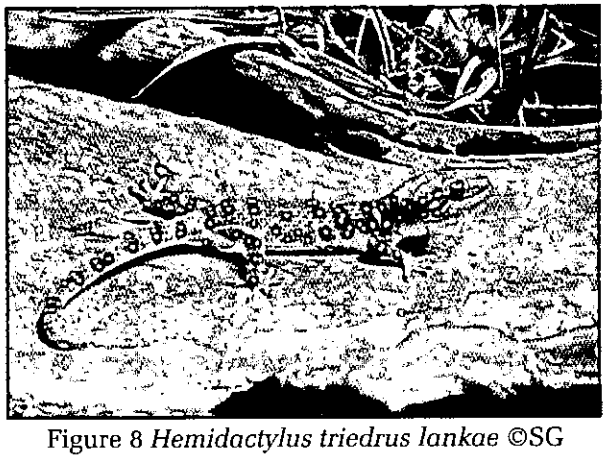


Figure 8 *Hemidactylus triedrus lankae* ©SG

Chapter 6
Snakes

Introduction

When compared with other reptiles such as skinks, geckos and agamids, snakes form the dominant reptile group in the Knuckles. During the survey, 35 species of snake were observed, of which 14 (40%) are endemic. Three species of geographical relicts belonging to two genera: *Aspidura* and *Haplocercus*, were among those encountered. The latter species has not previously been reported by other surveys in the region (Bambaradeniya & Ekanayake, 2003; IUCN & Forest Department, 1994; Ginge, 1994). It is highly possible that additional snake species of the families Colubridae, Uropeltidae and Typhlopidae may also have been discovered during the present study. Checking for fossorial and sub-fossorial snakes requires more specialised research and it is somewhat time consuming. Furthermore, literature suggests the presence of 9 additional species of snake (5 of which are endemic) from the Knuckles that were not encountered during our surveys in 2004 and 2005.

A wide variety of snakes can be observed inhabiting the Knuckles region. Some of these snakes are common, whilst others are rare and vulnerable. One species has been recorded only in the Knuckles (*Uropeltis Phillipsii*). Many require protection and all require further research. A number of observations regarding their ecology have been made during this project.

FAMILY: BOIDAE

Genus *Python* (Daudin, 1803)

***Python molurus* (Linnaeus, 1758)**

The only member of the family Boidae recorded from the Knuckles. The non-endemic Rock python, *Python molurus*, (Linnaeus, 1758), Pimbura, in Sinhala, was once common but is now believed to be rare. It is known to inhabit lowland forests, scrub land and even live in proximity to human habitation and places of other anthropogenic activities. Nocturnal in activity, the species is very good at concealing itself in leaf litter during the day, for up to several weeks at a time without moving.

During the project only one specimen was observed (Plate R8 Figure 1), an adult male on the roadside near Illukkumbura, surrounded by tropical mixed evergreen forest. The average total length of an adult is 3m. The length of the specimen observed was 1975 mm in total, with a snout to vent length of 1800 mm and a tail length of 175 mm. It weighed 4.85 kg, had a broken tail tip and a scar, which was infested with ticks. Whilst being measured, the python struggled and urinated. The urine was distinctly foul smelling - a method of deterrence.

Their diets are comprised mainly of vertebrates such as birds, deer and rodents. A resident of Loolwatte reported seeing a python feeding on a young wild boar.

A local resident reported seeing a dead specimen on the Loolwatte-Meemure road having been run over by a vehicle. Pythons are also killed for consumption - it is believed that their flesh contains medicinal properties. It is also believed that the rudimentary hind limbs on either side of the cloaca contain venom, which is administered once the python has wrapped itself around a target. Wearing python vertebra around the waist is said to be good for relieving rheumatic pains. Due to its large skin surface area and beautiful colouration, the skin trade once threatened the species.

Furthermore, pythons are often misidentified as Russell's Vipers (*Daboia russelii*) and are thus killed.

FAMILY: COLUBRIDAE
Genus *Ahaetulla* (Link, 1807)

***Ahaetulla nasuta* (Lacépède, 1789)**
Members of the more numerous Colubridae family were frequently encountered during the survey. Most commonly observed was the *Ahaetulla nasuta* which owes its generic name to the Sinhala: Ahaetulla, meaning 'eye snake', which is elaborated upon by the Tamil title Kankuththi pambu, which means 'snake which thrusts at the eye'. The slightly less evocative English term for the species is the Green Vine Snake, referring to the bright green scales and arboreal nature of the species. *Ahaetulla nasuta* is ovoviviparous and mildly venomous, but its fangs are ophisthoglyphous - located at the back of its mouth - and are only used on prey, at most a bite only causes mild discomfort to a human and the species would prefer just to evade sight.

The species is not endemic and is relatively common in the Knuckles. During the survey 19 specimens were observed in total. Of these, 3 were juvenile, of the 16 adults and sub-adults, 2 were male, 12 were female and the remainder could not be identified. Of the 16 adults and sub-adults observed, 8 were measured and were found to have a total length range of 850 to 1200 mm. The weight of 4 specimens was taken, and this ranged from 12 to 39g. Specimens were frequently observed in areas of disturbance, such as in scrub forests, areas of agriculture, near human habitation and on roadsides. They were also observed in Lower Montane, Upper Montane, Riverine and Tropical Mixed Evergreen Forests, all of which were disturbed. Whilst the IUCN records the species living up to altitudes of 1000 metres, they were recorded between the significantly higher altitudes of 277 and 1458m.

The species was almost always found on low vegetation approximately 1 metre above the ground, frequently at roadsides and usually basking in full sunlight. It is possible that predation occurs at this height from the ground. A number were observed sleeping at night. They appear to move to a higher position (approximately 2 metres above the ground) in trees and settle themselves at the end of branches, as far from the main stem of the tree as possible so as to avoid predation. One specimen was observed eating a live day gecko (*Cnemaspis* species) in its natural habitat. One specimen was observed dead on the Hettipola-to-Illukkumbura road, having been crushed flat by a vehicle. As the species is regularly observed basking on roadsides it is believed that this may be a common occurrence. Two colour variations were observed in the species. The usual colour of the ventral aspect is a mixture of light greenish yellow, but a number of specimens whose ventral aspect was chocolate brown in colour (Plate R8 Figure 2) were observed.

Traditionally this snake is not killed, but it is highly feared due to its reputation for seizing victim's eyes and was reportedly killed by residents of the Knuckles. The project attempted to avert this through conservation education by demonstrating that they are not deadly and do not cause extensive or permanent damage. They are fast and difficult to catch, usually much more interested in evading human presence than seizing an eye. They were only observed to strike only when held by a researcher, which was demonstrated to local residents wherever possible.

***Ahaetulla pulverulenta* (Duméril, Bibron & Duméril, 1854)**
The Brown Vine Snake, *Ahaetulla pulverulenta* (Plate R8 Figure 3) is the brown coloured relation of the Green Vine Snake, and is known in Sinhala as Henakandaya, meaning 'thunderbolt' which refers to the bite of the snake, indicating that it is so venomous that it causes a victim to go into paralysis and disintegrate as if struck by lightning. So feared is this snake that its shadow is even believed to be venomous. Of course, like the *Ahaetulla nasuta* this snake is only mildly venomous, with its envenoming fangs located at the back of the mouth, only for use on prey. At most, a bite victim will only be subject to mild localised swelling and discomfort. Whilst the project did not record any

specimens in the Knuckles, other researchers such as those of the IUCN have made a number of observations of the species in the area. It has mainly been recorded in the Wet Zone and is most likely to be found at lower altitudes of the range around the northern, eastern slopes and south eastern slopes.

Like the *Ahaetulla nasuta*, this species is not traditionally killed. However, in the Knuckles, it was again recorded that residents killed specimens through undue fear.

Genus: *Haplocercus* (Günther, 1858)
***Haplocercus ceylonensis* (Günther, 1858)**
The Black-spine or Mould Snake *Haplocercus ceylonensis* (Plate 10 Figure 3), known in Sinhala as Rathkarawala, meaning the red krait, is a sub-fossorial non-venomous snake with a striking characteristic red belly. Believed to be common, the species is nonetheless cited as Vulnerable according to the IUCN Red List. It is known to fall victim to agricultural practices, such as the application of pesticides and the ploughing of soil. Specimens inhabiting an altitude range of 1082 to 1250m were observed, although in other parts of the country they have been recorded as high as 1800m.

During this project 3 specimens were observed in total, all inhabiting disturbed Lower Montane Forest, sometimes in cardamom plantations. Two were found under rocks. De Silva, (1996) previously recorded that when a specimen is exposed, it remains motionless for a few minutes before attempting to escape. These observations were confirmed. One further specimen was observed in the leaf litter. It is believed that it was foraging at the time, as it was in close proximity to a skink. It is otherwise thought that worms are the main dietary component of the species. This observation was made at midday, although the species is believed to be nocturnal, with extensive activity being recorded around dusk and dawn.

All specimens observed were adults. Only one could be identified as female as it appeared to be gravid. The other two could not be identified. Literature records the average length of these species to be around 300mm (De Silva,1990). The female specimen found measured 352 mm in total, with a snout to vent length of 297 mm; a tail length of 55 mm and a weight of 8g.

Genus: *Aspidura* (Wagler, 1830)
***Aspidura brachyorrhos* (Boie, 1827)**
Aspidura brachyorrhos, known as Boie's rough-sided Snake (Plate R8 Figure 4) or Le madilla in Sinhalese, meaning blood snake, is a little known endemic and sub-fossorial species thought to inhabit an altitude range of 250 to 900m in the Wet Zone. Only one specimen was observed - a juvenile - on the Lakegala trail, at an altitude of 687m in a Tropical Mixed Evergreen forest. De Silva (1996) also records one specimen in Gammaduwa in the west of the range. The IUCN cites this species as Vulnerable. The average total length of an adult is recorded in literature as 300mm although little else is known about the species. It is often found in agriculture and in close proximity to other anthropogenic activities and is frequently killed on sight by humans who wrongly believe it to be venomous. It is suggested that the population inhabiting the Knuckles range needs to be studied in detail to ascertain its status.

***Aspidura trachyprocta* (Cope, 1860)**
Also referred to in Sinhala as the Le madilla or Dawala madilla meaning the blood snake; the Common rough-sided Snake (Plate R8 Figure 5), *Aspidura trachyprocta* is found in Upper Montane Forests and plantations up to 2100m in altitude. It is though to be highly susceptible to changes brought about by the implementation of agriculture in its habitat, particularly through habitat destruction, loss of habitat quality and poisoning through pesticides. It is endemic and classified as Vulnerable by the IUCN. The species is non-venomous and sub-fossorial and feeds largely on earthworms.

During the project 6 specimens were found, within an altitude range of 1043 to 1550m, spanning both Upper and Lower Montane forests. They were found in highly

disturbed habitats - including cardamom plantations - usually under leaf litter, in rotting vegetation or under stones. All of the specimens observed were adults. Two were female, one of which was gravid. The gender of the rest could not be identified. One specimen measured155 mm in total with a weight of 2g.

Genus: *Balanophis* (Smith, 1938)
***Balanophis ceylonensis* (Günther, 1858)**
The Sri Lanka Blossom Krait, known in Sinhala as the Mal Karawala, meaning flower krait, is a little known, slow moving species. It is terrestrial and forest dwelling, preferring the Wet Zone, particularly areas with high rainfall. It is a rear fanged moderately venomous snake, which reaches an average length of 450 mm. Although not recorded during this project in the Knuckles, Ginige (1994) observed it in Kalupahana during his research.

Genus: *Boiga* (Fitzinger, 1826)
Species of the genus *Boiga* are widespread, found throughout South Asia, tropical Africa and tropical Australia. They are commonly referred to as cat snakes, due to the elliptical shape of their pupil which resembles that of a cat. Five species inhabit Sri Lanka. They are all mainly arboreal and terrestrial and mildly venomous, although their bite causes only mild local reactions through a bite. Although there are no authentic records of any deaths, these species are widely killed by humans upon encounter. The species are also threatened by habitat loss caused by forest clearance.

***Boiga barnesii* (Günther, 1869)-**
Barne's Cat Snake (Plate 9 Figure 1) is Sri Lanka's only endemic *Boiga*; it is also the smallest species of *Boiga* in Asia. Known in Sinhala as Pandura Mapila, meaning Bush Cat Snake, the species is cited as Threatened according to the IUCN. The species is similar in appearance to *Boiga ceylonensis* and is found in the Wet and Intermediate Zones up to an altitude of 500m. It is nocturnal, arboreal and terrestrial, eating geckos, skinks and small lizards.
Whilst the IUCN has recorded *Boiga barnesii* in the Knuckles range, the species was not observed by Project Knuckles. Again, this is most probably due to the species' preference of lower altitudes, which were not the principal target of our study.

***Boiga ceylonensis* (Günther, 1858)**
The non-endemic Sri Lanka Cat Snake (Plate R8 Figure 6), *Boiga ceylonensis* is known as the Nidi mapila, which means sleeping snake in Sinhala. This is due to the belief that the bite of this species causes the victim to fall into a deep sleep (Rathnayake, 2001). The species is mildly venomous but rear fanged and of no cause of concern to humans. The species feeds on geckos, agamids, skinks and frogs. They are found in Tropical Mixed Evergreen, Lower and Upper Montane forests and grasslands up to an altitude of 1500m. The species was observed inhabiting an altitude range of 313 to 1191m, often in areas of anthropogenic activity such as human habitation and agriculture. Ten specimens were observed altogether, 2 of which were hatchlings and the rest adult. Of the adults, only 1 was male, 4 were female and the gender of the remaining 3 could not be identified. None of the females were gravid, although they are recorded to lay 5 - 10 eggs at a time. It was found that smaller specimens, namely the hatchlings, were much more aggressive and attempted to bite researchers much more readily than adults. The total length of the adults was found to range between 247 and 776mm with weights ranging from 26 to 36g. One of the specimens was observed shedding its skin.

***Boiga forsteni* (Dumeril, Bibron & Dumeril, 1854)**
The Forsten's Cat Snake (Plate R8 Figure 7) is the largest cat snake of the country. It is referred to in Sinhala as Naga mapila, meaning Cobra snake, the Tamil term, Poonai pambu is the less dramatic, simply meaning cat snake. Both terms refer to the species' tendency to hiss like a cat or cobra when faced with a threat. The species is also known somewhat unfairly as Le mapila or blood snake, in Sinhala due to the belief that a group of seven will creep into a person's house at night and form a chain,

hanging from the roof. The lowest will bite a victim's toe and slowly suck out the blood. All are said to feed through the first, until full, by which time the victim will be dead. An interesting aspect of folklore, this observation has never been scientifically verified. It is, however well documented that the species feeds on birds, small mammals and lizards, and being both nocturnal and arboreal, hunts for these in trees at night, utilising its mildly venomous rear fangs. When threatened the species raises the front portion of its body and forms loops with the rest of its body. It vibrates its tail and hisses.

Although the IUCN and various residents of the Knuckles have positively identified that the species inhabits the area, the species was not observed during our survey. This is most probably due to the species' preference of lower altitudes, which were not the principal target of our study.

***Boiga trigonata* (Schneider, 1799)**
The non-endemic Gamma Cat Snake (Plate R8 Figure 8) is known in Sinhala as the Ran Mapila or lined snake, referring to the markings on its body. The Tamil name Wollai pambu compares it to a thatched roof. The species has large eyes and white v-shaped marks along its body surface. Like *Boiga ceylonensis* this species is also rear fanged and mildly venomous. It is common throughout the country except at higher altitudes, and is most usually seen in the Dry Zone. The species is arboreal and nocturnal and eats geckos and small lizards.

During the survey 3 specimens were observed, all of which were adults. One was female and the gender of the other two could not be identified. The female was observed sleeping under a rock in a Tropical Mixed Evergreen forest, living in a nest of green ants which did not appear to be biting. The other 2 specimens were found in human habitation. One was foraging in a research lodge at night, whilst the other was dying, having possibly been attacked by chickens. The specimens were observed between the altitudes of 500 and 1191m. The total length of the female was 554 mm.

Genus: *Dendrelaphis* (Boulenger, 1890)
Dendrelaphis bifrenalis (Boulenger, 1890)
Boulenger's Bronze Back Snake (Plate R9 Figure 2), known in Sinhala as Panduru Haldanda meaning the Bush Paddy Stem Snake, is a fast moving diurnal arboreal snake. The average total length of an adult is 750 mm (De Silva, 1990) although the specimen recorded by the project measured 1211 mm. The species is not endemic, but little is known about its behaviour and ecology. The specimen recorded by the survey was a non-gravid female weighing 834g, found at an altitude of 113m in a Tropical Mixed Evergreen forest. Whilst further research on the species is recommended, it must be noted that due to the agility of the species they are very hard to catch, identify and measure.

***Dendrelaphis caudolineolatus*, (Günther, 1869)**
The Stripe-tailed Bronze Back Snake (Plate R9 Figure 3) is known in Sinhala as the Viri Haldanda or lined paddy system snake, and again in Tamil as Komberi Moorkhan or tremendous tree climber snake. Another fast moving arboreal and diurnal snake, of which 4 specimens were observed, all of which were adults. Two were females and 2 were males. One specimen was observed on low vegetation, 2 on trees and the fourth was found dead on a road having been killed by a vehicle. All were observed in disturbed habitats - one was found inside a shop - although the other 3 were in relatively close proximity to Lower Montane forest, albeit disturbed. They were observed ranging between the altitudes of 951 and 1212m, with total lengths ranging from 737 to 914mm and weights ranging from 20 to 52g. Very similar in appearance to *D. tristis*, very little is known of the biology and behaviour of this species.

***Dendrelaphis tristis*, (Daudin, 1803)**
The Common Bronze Back Snake (Plate R9 Figure 4) is known in Sinhala as Tura Haldanda or the Tree Paddy Stem Snake - the Tamil term Komberi Moorkhan applies to this species as well as *D. bifrenalis*. The species is not endemic and was commonly observed in Tropical Mixed Evergreen, Riverine and Scrub forests. It was most

frequently found in areas of disturbance, often in close proximity to anthropogenic activity such as habitation and agriculture. The arboreal species possesses the ability to jump between trees and feeds on reptiles, amphibians, insects and small birds. It is diurnal in nature. The average total length of the species is 750mm. Seven specimens were observed altogether, all of which were adults. However, due to their speed, only one was caught - a gravid female, measuring 984mm in total length and weighing 51g. The 7 specimens were observed at altitudes ranging from 211 to 722m. When threatened, the species moves its head from side to side. Upon capture, the female specimen bit a researcher.

Genus: *Oligodon* (Boie, 1827)
***Oligodon sublineatus* (Duméril, Bibron & Duméril, 1854)**
Duméril's Kukri snake (Plate R9 Figure 5) is known in Sinhala as Pulli Dath Ketiya, meaning the spotted many toothed snake. It is endemic to Sri Lanka but is considered as only Lower Risk - near threatened by the IUCN. The species has two characteristic dotted lines on its ventral side, and is the most common of the Kukri snakes in the Knuckles range. It is terrestrial and diurnal in nature. Twelve specimens were observed altogether, all of which were adults. Five were female - 1 of which was gravid - 1 was male and the gender of the remaining 6 could not be identified. Literature records that the average total length of an adult is 200mm. The total length of 6 measured specimens ranged from 60 to 283mm and weighed from 6 to 13g. Recorded by the IUCN to reach up to altitudes of 1200 m, specimens were recorded at altitudes ranging from 434 to 1136m, in Lower Montane, Riverine and Tropical Mixed Evergreen forests as well as in areas of anthropogenic activity such as agriculture. Specimens were usually found under rocks and logs and in leaf litter. On encounter, humans often kill *O. sublineatus* believing them to be hatchlings of the Russell's Viper.

***Oligodon taeniolata ceylonicus* (Wall, 1921)**
The Variegated Kukri Snake, referred to in Sinhala as Vairi Dath Ketiya or the variegated many toothed snake, is another endemic *Oligodon*, considered Vulnerable by the IUCN. The average total length of an adult is 300mm and the species is diurnal and terrestrial in nature. Whilst recorded by the IUCN and Ginige (1994) in the Knuckles, no specimens were observed by Project Knuckles.

Genus: *Macropisthodon* (Boulenger, 1893)
Macropisthodon plumbicolor palabariya (Deraniyagala, 1955)
The Green Keel-back Snake (Plate R9 Figure 6) owes its scientific sub-species name to the Sinhala *Palabariya*, meaning green snake. The Tamil term Pachchai Neerkkoli meaning green water dweller indicates the aquatic associations of the species which is frequently observed in close proximity to water, in tropical mixed evergreen, lower montane and scrub forests, up to an altitude of 1000m. The species *M. plumibicolor* is widespread in Sri Lanka and southern India, although the sub-species *palabariya* is endemic to Sri Lanka. *M. plumbicolor* is bright green and plump in appearance. It is ovoviviparous, diurnal and terrestrial in nature and feeds on amphibians. Individuals have been known to mimic the cobra by raising their head and flattening their neck. The IUCN cites the sub-species as Vulnerable.

The project recorded 3 specimens, all of which were dead adult males on the road, having been run over by vehicles. The average total length of an adult is 400mm, although the specimens recorded ranged from 522 to 564mm and 41 to 69g in weight. They were observed in roughly the same locality, on the Hettipola-to-Illukkumbura road, at an altitude range of 264 to 552m. All 3 locations were surrounded by Tropical Mixed Evergreen forest, which, although disturbed, were not extensively so, possibly due to their proximity to the Illukkumbura forestry office.

It was noted that the 3 specimens observed in the Knuckles exhibited a variance in colouration from other specimens recorded in the country. The Knuckles individuals had green dorsal and white ventral aspects.

The black line usually found between the eye and neck of the species was also absent.

Genus: *Sibynophis* (Fitzinger, 1843)
***Sibynophis subpunctatus* (Duméril, Bibron & Duméril, 1854)**
Jerdon's Polyodent Snake (Plate R9 Figure 7) is known in Sinhala as Dathigomaraya, which means many toothed one. The species is diurnal, terrestrial, non-venomous and non-aggressive. It is known to feed on snake species of the genus *Aspidura* and *Typhlopidae* (De Silva, 1990). The species average length is 250mm and is found under debris, logs and rocks. One specimen was found in Hettipola near human habitation but escaped before measuring. The species is distributed throughout the lowlands of Sri Lanka in all of the climatic zones. It is also found in India.

Genus: *Ptyas* (Fitzinger, 1843)
***Ptyas mucosa* (Linnaeus ,1754)**
The common Rat snake (Plate R15 Figure 2), Gerandiya in Sinhala and Sarai Pambu or 'straight snake' in Tamil is a widespread species, recorded from as far a field as Turkmenistan and China. The main component of the species' diet is rats, hence its name, but it is also frequently found to eat other reptiles, birds, small mammals, amphibians, bats and other snakes. The IUCN considers it Lower Risk - near threatened. The study encountered 5 specimens, 4 of which were adult and 1 was sub-adult. Almost all specimens hissed whilst trying to evade what they perceived to be a threat. One of the adults was male, whilst the gender of the remaining individuals could not be identified. This male was the only one measured. *Ptyas mucosa* is the second largest snake in Sri Lanka, and whilst the average length for the species is 1500mm, this male individual was 2325mm, 350mm longer than the python recorded by the project. It also had a broken tail tip and three old scars on its body. All of the Rat snake specimens were observed at altitudes ranging from 553 to 1110m, in disturbed habitats, either human habitation or highly disturbed Lower Montane forest. They are commonly killed after being mistaken for a krait or cobra, although they should be welcomed for their vermin controlling abilities.

Genus: *Xenochrophis* (Günther, 1864)
***Xenochrophis asperrimus* (Boulenger, 1891)**
The Sri Lankan Keel-back Snake (Plate R10 Figure 1) is known in Sinhala as the Diya Bariya and in Tamil as Tanni Pambu, which both mean water snake. This endemic species is aquatic in nature and common in distribution. It is found in disturbed areas, particularly where there are waterways, usually in or near scrub forest and frequently in Riverine forest. It feeds on fish and amphibians and can be found up to altitudes of 1500m. The IUCN cites it as Lower Risk - near threatened. Two specimens were observed in the Knuckles, a dead adult and a live juvenile. The juvenile was swimming in an artificial waterway at Illukkumbura. While the average total length of an adult is recorded as 650mm, the adult recorded during this project was only 537mm, and weighed 52g. This snake is often killed in the belief that it is venomous.

***Xenochrophis piscator* (Schneider, 1799)**
The Checkered Keel-back Snake (Plate R9 Figure 8) is known as the Diya Naya in Sinhala and Neer Nagam in Tamil. Both names mean water cobra, referring to the species' tendency to expand its neck region and rear up a little, thus mimicking a cobra. The species is non-endemic and relatively widespread throughout South and South East Asia from Thailand to Afghanistan. It is active both day and night and can be found in disturbed areas, particularly where there is water, up to an altitude of 1000m It feeds on fish and amphibians but is non-venomous. Only one live specimen (adult) was encountered near human habitation and the other 6 specimens were found as victims of road kill along waterways in Hettipola. The average length of the species is 750mm.

Genus: *Amphiesma* (Duméril, Bibron & Duméril, 1854)

***Amphiesma stolatum* (Linnaeus, 1758)**
The Buff-striped Keel-back Snake (Plate

R10 Figure 2) is known in Sinhala as Aharukukka which means the 'hungry pup', referring to its large appetite for prey such as frogs and fish. The Tamil name, Kaliyan Kutti means young water devil in reference to the species' frequent proximity to water when encountered. This non-endemic species is common in the lowlands in grasslands, forests and areas of anthropogenic activity such as habitation and agriculture, especially if there is nearby water. Two specimens were observed, one adult and the other a sub-adult. Both were female and neither was gravid. While one was found at 138m in Tropical Mixed Evergreen forest, the other was found at 996m in Lower Montane forest, indicating a wide altitudinal preference range in the Knuckles region. The sub-adult was 362mm in total length and the adult was 372mm and 10g in weight.

Genus: *Coelognathus* (Fitzinger, 1828)
***Coelognathus helena* (Daudin, 1803)**
The Trinket snake (Plate R10 Figure 3), known in Sinhala as the Katakaluwa or black mouthed snake and in Tamil as the Kattu Pambu or banded snake is the subject of some peculiar but nonetheless fascinating folkloric beliefs. It was widely believed in posterity that if it were to bite a victim, it would climb a nearby tree and wait for the victim to die before returning to the ground. Traditional snakebite medicine records that whilst the snake remained in the tree, no treatment would be effective in managing the victim, thus the snake would first have to be lured to the ground, either using various charms whilst chanting incantations or by making the snake believe that the victim was dead. The latter would require the family of the victim to stage a mock funeral in the vicinity of the tree where the snake was believed to be watching, thus tricking it into believing that the victim was dead, drawing it to the ground and allowing treatment to commence.

The trinket snake is of course entirely non-venomous.. It feeds largely on rats but is also known to feed on geckos and other reptiles, amphibians, and small birds. It is found at altitudes up to 1000m in lowland, Tropical Mixed Evergreen and Lower Montane forests, plantations and other areas of agriculture, particularly close to water. The species is terrestrial, but as was correctly observed by traditional snakebite physicians it possesses an ability to climb trees.
Two specimens were observed, one at an altitude of 261m and the other at 931m. However, both specimens were dead on the road, having been killed by vehicles, marking this as a considerable threat to the species.

Genus *Liopeltis* (Fitzinger 1843)

***Liopeltis calamaria* (Günther, 1858)**
The Reed Snake (Plate 10 Figure 4) is known in Sinhala as Punbariya, which again associates the snake with reeds, where it is often observed. It is a terrestrial, diurnal and non-aggressive snake, feeding on frogs and geckos. It is usually found close to aquatic habitats, at a wide range of altitudes, having been recorded in all 3 of the Sri Lankan peneplains. However, the species is far from common. Only 1 specimen was encountered during the study: an adult male, at an altitude of 676m in a highly disturbed area of agriculture. This was the first record of the snake in the Knuckles region. The average total length of the species is recorded as approximately 250mm. The specimen encountered by the project conformed to this average, measuring 267mm.

Genus: *Chrysopelea* (Boie, 1826)
***Chrysopelea ornata* (Deraniyagala, 1945)**
The Ornate Flying snake (Plate R10 Figure 4) is a non-endemic species. The Sinhala term for the snake, Malsara, meaning adorned with flowers refers to the snake's brightly coloured red, yellow and black rosette markings, whilst the Tamil Parakkum Pambu or flying snake refers to its gliding ability, shared by the endemic species *C. taprobanica*. They are diurnal, oviparous and arboreal, known to feed on reptiles, amphibians, birds, rodents, bats and other snakes – although it is a gecko specialist, feeding on them voraciously.

The IUCN cites the sub-species as

Threatened, inhabiting Wet, Dry and Intermediate Zone lowlands up to 200m. However, one adult was observed in the village of Narangamuwa, at an altitude of 600m, thus increasing the altitude range of the species. This specimen was found attempting to feed in a chicken coup, indicating both a diversification of its diet and a relative indifference to proximate humans.

***Chrysopelea taprobanica* (Smith, 1943)**
The Sri Lankan Flying snake (Plate R10 Figure 5) is known in Sinhala as Dangara Danda, meaning the 'zig-zag' marked snake. Despite unconfirmed reports of its sighting at high altitudes in southern India, the species is currently considered endemic to Sri Lanka. The 'Flying Snake' Genus are characterised by their ability to glide for large distances between trees - up to 50m. They are diurnal, oviparous and arboreal, known to eat reptiles, amphibians, birds, rodents, bats and other snakes. They are found in the Dry and Intermediate Zones at lower altitudes, up to 200m. The IUCN cites the species as Threatened and whilst they document its presence in the Knuckles, although the project didn't observe any specimens.

Genus: *Lycodon* (Boie, 1826)
***Lycodon aulicus* (Linnaeus, 1754)**
The Wolf / House snake (Plate R10 Figure 6) is known in Sinhala as the Aluradanakaya, alu meaning ash coloured and radanakaya implying enlarged canine teeth, or Alu Polonga meaning 'ash viper' and in Tamil as Vala Panayan, meaning simply the smooth snake. It is a nocturnal, terrestrial snake frequently found in human habitation. It is relatively aggressive and doesn't hesitate to bite when disturbed. When threatened it may also coil its body into a ball and is known to release foul smelling excrement to deter any possible predation. Non-venomous, the species is widely killed nonetheless. One adult specimen was recorded by the project under a log in human habitation at an altitude of 261m. The specimen was 288mm in total length and weighed 12g.

***Lycodon striatus sinhaleyus* (Deraniyagala, 1955)**
Shaw's Wolf Snake (Plate R10 Figure 7) is known in Sinhalese as Kabara Radanakaya meaning variegated snake with large canines, whilst the Tamil term, Vellikkol Varayan, means the lined 'balance-stick' snake. The species is recorded at altitudes up to 500m, and is frequently found in human habitation. It is often mistaken for a krait and is thus killed by humans. Currently, the species is threatened by urbanisation and agricultural expansion. The IUCN cites the species as Vulnerable. The project encountered only 1 specimen, an adult female in human habitation at an altitude of 248m. The individual was 223mm in total length and weighed 3.5g.

FAMILY: ELAPIDAE

Genus: *Bungarus* (Daudin, 1803)
***Bungarus caeruleus* (Schneider, 1801)**
The Common Krait (Plate R11 Figure 1) is known in Sinhala as the Thel Karawala and in Tamil as Yennai Viriyan, both of which mean oil krait which alludes to the glistening shine of the scales of the snake. This species is terrestrial, nocturnal and highly venomous. It is responsible for many human fatalities. It is found mainly in the Dry and Intermediate Zones, in thin, often disturbed lowland forests, frequently in close proximity to human habitation. During the day, they are known to hide under debris, in rat burrows or termite mounds. They have short fangs adapted to feeding on snakes, although rodents, skinks, geckos and other reptiles are also known to comprise a portion of their diet. Acts of cannibalism have been recorded. One adult female was observed at an altitude of 113m on the ground in an area of human habitation. The average size is recorded at around 750mm (De Silva, 1996). This individual's total length was 774mm and its weight was 89g.

***Bungarus ceylonicus* (Günther, 1864)**
The Ceylon / Sri Lanka Krait (Plate R11 Figure 2) is known in Sinhala as the Madu Karawala or ringed krait and in Tamil as the Yennai Panayan or Oil viper. This highly venomous sub-species is endemic

and cited by the IUCN as Vulnerable. It is nocturnal in nature and hides during the day in cool damp areas under debris, rocks and logs, frequently in human habitation. Its reproductive habits are unknown. The project recorded one specimen: a sub-adult found in human habitation. This particular specimen was found at 1191m, although literature (Das and De Silva, 2005) suggests the species is found in wet parts of the Intermediate Zone forests up to only 1000 m in altitude. The average total length of an adult is approximately 600 mm. The sub-adult was 311mm in total. Unfortunately, it had been killed by a local resident, an occurrence which is believed to be common, owing to the deadly nature of the snake.

Genus: *Naja* (Laurenti, 1768)
***Naja Naja* (Linnaeus, 1758)**
The Spectacled Cobra (Plate R11 Figure 3), known in Sinhala as Nagaya, a corruption of the sanskrit *Nag* meaning cobra, and in Tamil as Nalla Pambu, meaning good snake is both highly feared and highly revered throughout Sri Lanka. The species is of course highly venomous but, unlike most other snakes in the country, is rarely killed as it is closely associated with both Buddhism and Hinduism, being a protector of wealth, water, agriculture and property. Most famously, the cobra was said to use its hood to shelter Lord Buddha from the rain during his period of meditation. It is considered auspicious to have a visitation by a cobra. Other beliefs surrounding the species include one whereby the partner of a killed cobra will seek revenge upon the killer. Many are thus afraid to kill these snakes. The species earns its name 'Spectacled Cobra' from the spectacle marking on the dorsal aspect of its hood.

The main component of the species' diet is rodents and other small mammals. It is thus drawn to areas of anthropogenic disturbance such as human habitation or agriculture where rats are more common. It is mainly diurnal although nocturnal activity has been recorded. They have been widely reported in the Knuckles, both by the IUCN and local residents and are believed to be common. There are confirmed reports from local hospitals of envenoming and even death caused by cobras. However, during the project no specimens were encountered. This is most likely because human habitation was not as extensively surveyed during the project as less disturbed areas such as Montane and Tropical Mixed Evergreen forests where the species is less likely to be found.

FAMILY: TYPHLOPIDAE

The Typhlopids are primitive snakes, believed to have arrived in Sri Lanka relatively early in comparison to other snakes. Unusual in appearance and biology, there are a number of traditional beliefs concerning them, including the belief that they crawl into people's ears as they sleep (de Silva, 1990).

The project observed 8 specimens of which the following were identified. It is possible that one, maybe two previously un-described species were also recorded by the project. Further research is necessary to identify the nature of these specimens.

Genus: *Ramphotyphlops* (Fitzinger, 1843)
***Ramphotyphlops braminus* (Daudin, 1803)**
The Brahminy Blind Snake (Plate R11 Figure 4), known in Sinhala as the Dumuta Kanaulla or Black Blind Snake and interestingly in Tamil as the Sevittu pambu or Deaf Snake, is widespread throughout the world. This was achieved when the snakes were transported in the roots of plants sold commercially to households in America, Africa, mainland Asia and even a number of islands in the Pacific. They are usually found in soil, under rocks or leaf litter or even exposed on the surface of the soil following rain, often in disturbed lowland forests or around human habitation in the Dry Zone. They are nocturnal in nature and one was observed foraging in a termite mound at night. They feed on termites, ants, insect larvae and earthworms. The species is parthenogenic, meaning that they are all female, and can produce eggs without mating. As a defence mechanism the species utilises a spine and defecates foul smelling faeces to deter any potential predators.

Four specimens were encountered, all of which were adults, one of which was gravid. They were found inhabiting an altitude range of 170 to 591m and the average total length of the species is approximately 150 mm.

Genus: *Typhlops* (Oppel, 1811)
***Typhlops porrectus* (Stoliczka, 1871)**
There is no common name for this snake in English, Sinhala or Tamil (Plate 10 Figure 5). Furthermore, no biological or behavioural observations are available as it has been little studied. It is believed to inhabit forests up to 1300m and attain an average length of 285mm. It is non-venonomous and non-endemic. One adult specimen was encountered in the vicinity of Yahangala, the first record of the species in the Knuckles region.

FAMILY: UROPELTIDAE

The Uropeltid snakes are primitive, believed to have arrived in Sri Lanka during the Pliocene period and evolved after this migration (De Silva, 1990). It has been hypothesised that the ancestral migrant was considerably different to present day Uropeltid snakes and perhaps more akin to the species *Cylindrophis maculata*.

Genus: *Uropeltis* (Cuvier, 1829)
***Uropeltis phillipsi* (Nicholls, 1929)**
Phillips's Shield Tail Snake (Plate 10 Figure 1) known in Sinhala as Iriwakatulla, meaning lined snake with a pointed snout and in Tamil as Manuweli Pambu. The species is endemic to Sri Lanka and is considered by the IUCN to be Critically Endangered. The reasoning behind this is the species' apparent confinement to the Maousakanda estate around Gammaduwa. This area is a part of the Knuckles region but is not protected by conservation laws. Thus, the snake is vulnerable to any changes in this small area. It is fossorial, and believed to be sensitive to soil thickness and quality. It is particularly vulnerable to threats associated with agriculture, such as ploughing and the application of pesticides. The degradation of habitation is considered a significant threat to the species especially as much of the Mouasakanda is cultivated for cardamom. The study recorded 5 specimens: 3 adults and 2 sub-adults, all within the Gammaduwa region. Two specimens were female and neither was gravid. The average length is recorded in literature at approximately 230mm, (Das & de Silva, 2005) and the specimens measured by us ranged from 190 to 268mm. The specimens were observed between 940 and 1115m in altitude, and all were found under rocks in highly disturbed Lower Montane forest.

Many local residents fear these species, falsely believing that they are venomous. One ex-cardamom cultivator was found to have left his employment through fear of working alongside these snakes. Additionally, throughout the Knuckles, there is a belief that should a Uropeltid snake tie a knot around your fingers, it will never again untie. Thus, many of these harmless snakes are needlessly killed by unduly worried residents.

***Uropeltis melanogaster* (Gray 1858)**
The Black-bellied Shield Tail Snake (Plate 10 Figure 7) is known in Sinhala as Kalurakathudulla, meaning snake with a black pointed snout or Kospoththa, which refers to the greenish yellow tinge on the underside of the species. This fossorial snake is thought to inhabit forests at altitudes of up to 1000m in the Central province hills. The species is considered Vulnerable by the IUCN. However, it is not certain whether or not the species observed in the Knuckles were in fact *U. melanogaster*. This was simply the closest identity that emerged whilst using species keys. Further research is required to confirm the identity of this species.

We observed 36 specimen's altogether: 32 adults; 3 sub-adults and 1 juvenile. 7 were female - 1 of which was gravid; 1 was male and the gender of 28 specimens could not be identified. The total length of the specimens ranged from 190 to 271mm. The weight taken from 1 specimen was 11g. The species was observed in human habitation, pine, tea, acacia and cardamom plantations,

and Lower and Upper Montane and Riverine forests. All habitats were disturbed except for 1 which was an Upper Montane forest. Specimens were found in soil, root systems, under logs, under rocks, in anthropogenic drainage ditches and 1 was observed on the surface of the ground, being eaten by ants. It must be noted that *U. melanogaster* was not observed inhabiting Gammaduwa, indicating that different species of *Uropeltid* snake do not appear to live sympatrically to one another in the Knuckles range. The species was found to be viviparous. Upon dissection, one dead specimen was found to contain 3 fully developed embryos which were also dead (Plate R2 Figure 3). The species is believed to be particularly vulnerable to threats associated with agriculture, such as ploughing and the application of pesticides. The degradation of soil through agriculture could pose a significant threat although healthy populations of the species were observed in habitats which had been degraded for a considerable amount of time.

Genus: *Rhinophis* (Hemprich, 1820)
***Rhinophis drummondhayi* (Wall, 1921)**
One species which appeared similar to *R. drummondhayi* was observed in Elkaduwa. The English name for this species is Drummond-Hay's Earth Snake (Plate 10 Figure 6), and the Sinhala name is Thapothudulla. It is a non-venomous endemic fossorial snake, reaching an average length of 330mm and known to inhabit forests up to 1200m in altitude. However, it is uncertain if the specimen observed in Elkaduwa was indeed *R. drummondhayi* - which would be a first observation for the Knuckles - or indeed if it is a new species. Results are pending analysis and further research is suggested in the Elkaduwa area.

***Rhinophis philippinus* (Cuvier, 1829)**
Peter's Earth Snake (Plate R11 Figure 5) is an endemic, nocturnal, fossorial snake which eats earthworms and bears live young. It lacks any particular Sinhala or Tamil name, due to its insignificant external appearance. The study recorded 11 specimens, all of which were adults. Three were female, 4 were male and the gender of the remaining 4 could not be identified. One of the females was gravid. Of those measured, the total length ranged from 250 to 255mm, and the weight from 3 to 7g. The specimens were observed under rocks and logs, inhabiting soil and root systems, with penetrometer readings ranging from 0.5 to 1.7. They were found in human agriculture, Lower Montane, Riverine and Tropical Mixed Evergreen forests.

***Rhinophis blythii* (Kelaart, 1853)**
Blyth's Shield Tail Snake, known in Sinhala as Gomarathudulla, meaning variegated snake with pointed snout, is a fossorial ovoviviparous species found throughout the Central Hills. It is non-venomous and feeds on earthworms. They are often observed living in colonies, in root systems and soil under decaying vegetation. Observed in Kalupahana by Ginige (1994), the specimen was not observed by Project Knuckles.

Genus: *Pseudotyphlops* (Schlegal, 1839)
***Pseudotyphlops philippinus*, (Schlegal, 1839)**
The Large Shield Tail Snake (Plate R11 Figure 6), known in Sinhala as the Maha Bim Ulla meaning large snake which digs into the soil is the largest Shield Tail Snake species in the world and is endemic to Sri Lanka. The species has been recorded by the IUCN in the Knuckles was not observed by us during the project. The species is considered Endangered. It is possible, however, that previous records of the species in the area were simply misidentifications of the species *Rhinophis philippinus*.

Genus: *Cylindrophis* (Wagler, 1828)
***Cylindrophis maculatus* (Linnaeus, 1758)**
This endemic Pipe snake (Plate R11 Figure 7) is the only representative of the visually striking and unusual genus, which inhabits Sri Lanka. It is known in Sinhala as the Depath Naya, inferring that the snake has a head at each end of its body and is considered to be Low Risk - near threatened by the IUCN. It is found at altitudes of up to 650m, often in areas of disturbance such as in agriculture and human habitation. It is occasionally killed in the belief that it is venomous.

FAMILY: VIPERIDAE

Genus: *Daboia* (Gray, 1842)
***Daboia russelii russelii* (Shaw & Nodder, 1797)**
The much feared Russell's viper (Plate R11 Figure 8) is known in Sinhala as the Tith Polonga meaning spotted viper and in Tamil as Kannadi Viriyan, which refers to the spectacled design on the dorsal side of the viper. This viper is responsible for the highest rate (40%) of death due to snakebite envenoming in the country and causes a large number of annual hospitalisations. There are confirmed cases of death caused by this viper's signatory venom in the Knuckles region. It is not endemic. The average total length of an adult is approximately 900 mm. Two badly decomposed adults were found in Kobonila, which had been killed by villagers. While this species has been recorded by the IUCN and has been positively identified by both Forestry officers and local residents in the Knuckles, the study did not encounter live specimens. Although this species is likely to be common, it is most probably not encountered due extensive sampling was not conducted in human habitation - a habitat type preferred by the species, where it hunts rats, a main component of its diet.

Genus: *Hypnale* (Fitzinger 1843)
***Hypnale hypnale* (Merrem, 1820)**
Merrem's Hump nose viper (Back Cover Figure 5) is known in Sinhala as Polon Thelissa, meaning the upturned lip viper, and in Tamil as the Kopi Viriyan, meaning the coffee viper, referring either to its rich brown colouration or perhaps its presence in the Sri Lankan coffee plantations of the nineteenth century. This non-endemic species is responsible for the highest morbidity incidences of snakebite in the country, although it is not as venomous as other snakes such as the Cobra or Russel's viper. A total of 28 specimens were recorded, 25 of which were adult, 1 sub-adult and 2 juvenile. Twelve were female, 8 were male and the gender of a further 8 could not be identified. Two of the female specimens were gravid. The average total length of an adult is 300 mm, and the adult total length ranged from 280 to 498mm, with weights ranging from 12 to 59g. The species was found inhabiting Dry Zone agriculture, Kandyan Forest Gardens, Lower and Upper Montane, Riverine and Tropical Mixed Evergreen forests, the majority of which were disturbed. They were found on low vegetation, on roads and under rocks, logs, anthropogenic wood piles and leaf litter. In terms of injuries, one specimen was observed to have an abscess on its right fang. Many are killed on sight, which is a frequent occurrence in the agriculture industry.

***Hypnale nepa* (Laurenti, 1768)**
Millard's hump nose viper (Plate R12 Figure 1), known in Sinhala as the Mukalan Thelissa or forest viper, or in Tamil as the Viriyan Pambu, simply meaning 'viper snake' is a terrestrial and endemic viper, similar in appearance to *H. hypnale*. It is considered Vulnerable by the IUCN. Thought to inhabit altitudes of up to 1800m, during the project the species was recorded between the altitudes of 476 and 1497 m, in upper and lower montane and tropical mixed evergreen forests - all of which were disturbed. Five specimens were observed in total, 4 of which were adults, and 1 of which was a male hatchling. Two of the adults were gravid females and the gender of the remaining 2 could not be identified. The total length of 1 specimen was 265mm with a weight of 12g. Like *H. hypnale*, many are killed on sight, which frequently occurs in the agriculture industry.

Genus: *Trimeresurus* (Sonnini & Latreille, 1801)
***Trimeresurus trigonocephalus* (Sonnini & Latreille, 1801)**
The striking Green pit viper (Plate R12 Figure 2 & Plate 10 Figure 8) is known as Pala Polonga in Sinhala and Pachchai Viriyan in Tamil, both of which mean green viper. The species is endemic and considered by the IUCN to be Vulnerable. It is Sri Lanka's only arboreal viper. The snake has good usage of its tail and can hang from branches using only the latter portion of its body for support. The study observed 7 specimens, 4 of which were

adult, 1 sub-adult and 2 juveniles. Six specimens were female and 1 was male. None were recorded as gravid. The species was recorded at a altitude range of 618 to 1458m, inhabiting Tropical Mixed Evergreen, Lower and Upper Montane forests, all of which were disturbed. They were usually found inhabiting low vegetation such as bushes – including tea – or cardamom stems. One specimen was observed sleeping in a tree hole during the day. Despite being arboreal another specimen was observed in leaf litter at night. It is suspected that they may descend to the ground in search of food. Being nocturnal, it is easier to locate specimens at night, their bright colouration is easily picked up with torch light. The average total length of this species is 750mm and ranging from 516 to 940mm, with weights ranging from 42 to 184g. The largest, both in length and weight was the male specimen observed.

This individual was found sleeping in a bush in close proximity to a foot path. Several researchers brushed past the bush and unknowingly came into contact with the snake. It did not react to their presence.

The IUCN has reason to suspect that the species is smuggled internationally for the pet trade. This is certainly believable, being such a beautiful snake. Its bite is nonetheless a serious consideration. It was recorded during the study period one tea picker in a tea estate in the southern Knuckles being bitten by a *T. trigonocephalus*. In addition to a panic attack, the victim suffered severe but localised pain and swelling. The viper was killed, a common fate for those who encounter humans, especially after biting one.

Plate R8 - Snakes 1

Figure 1 *Python molurus molurus* ©SG

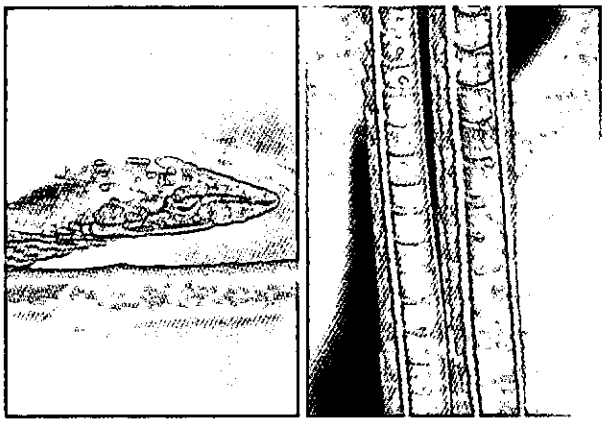


Figure 2.1 *Ahaetulla nasuta* ©SG Figure 2.1 ventral aspect ©SG

Figure 3 *Ahaetulla pulverulentus* ©AdS

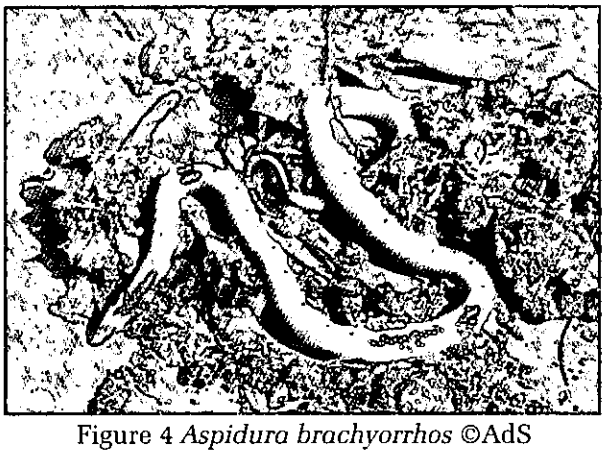


Figure 4 *Aspidura brachyorrhos* ©AdS

Figure 5 *Aspidura trachyprocta* ©SG

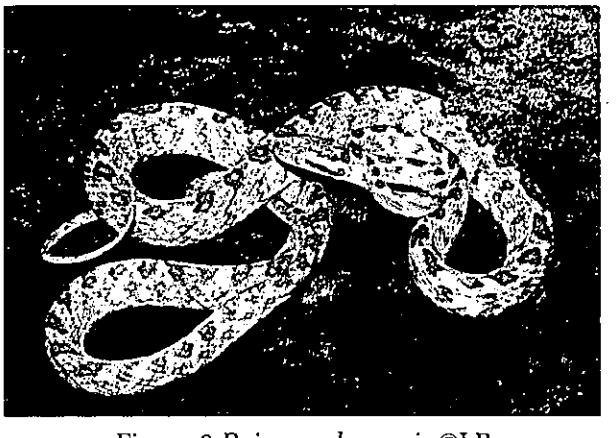


Figure 6 *Boiga ceylonensis* ©LP

Figure 7 *Boiga forsteni* ©SG

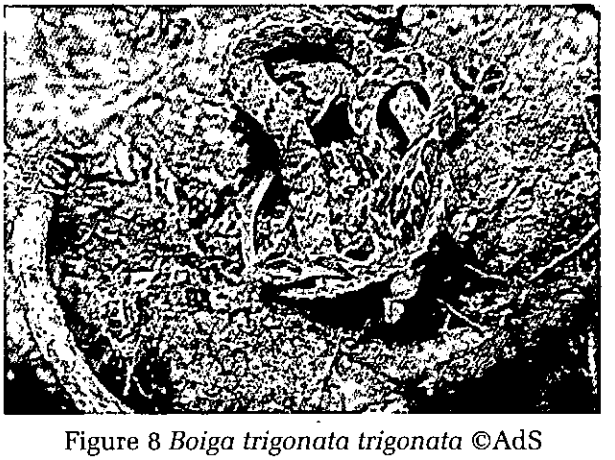


Figure 8 *Boiga trigonata trigonata* ©AdS

Plate R9 - Snakes 2

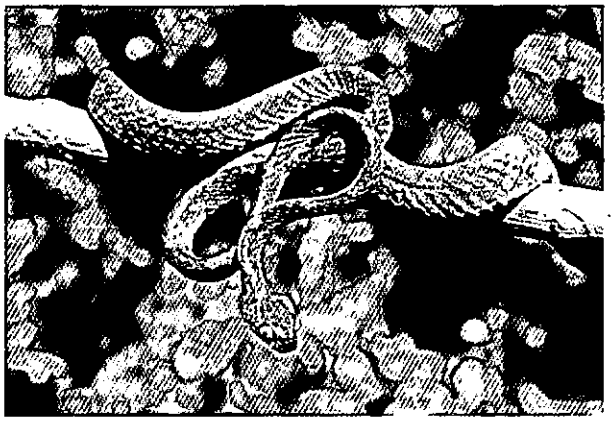


Figure 1 *Boiga barnesii* ©AdS

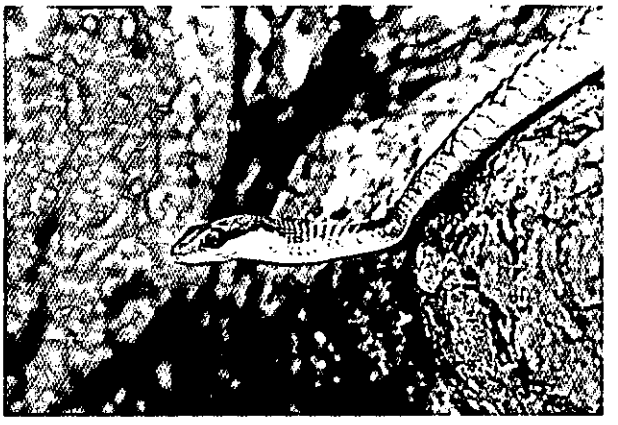


Figure *2 Dendrelaphis bifrenalis* ©AdS

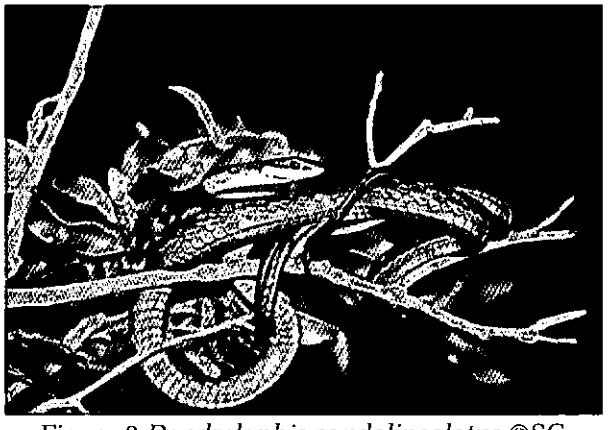


Figure 3 *Dendrelaphis caudolineolatus* ©SG

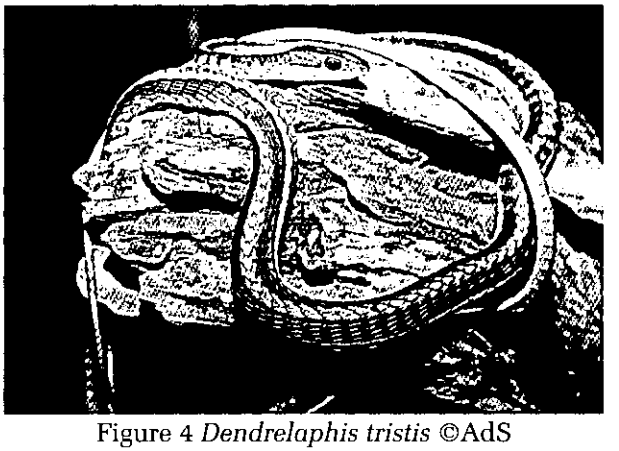


Figure 4 *Dendrelaphis tristis* ©AdS

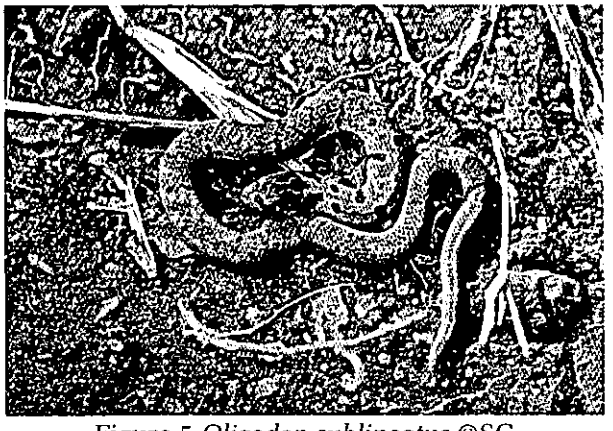


Figure 5 *Oligodon sublineatus* ©SG

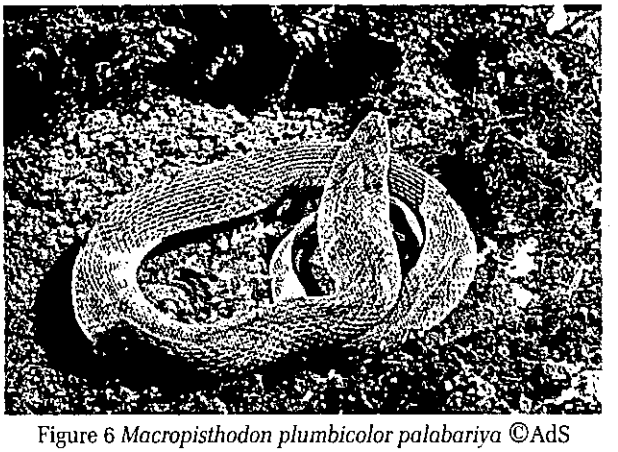


Figure 6 *Macropisthodon plumbicolor palabariya* ©AdS

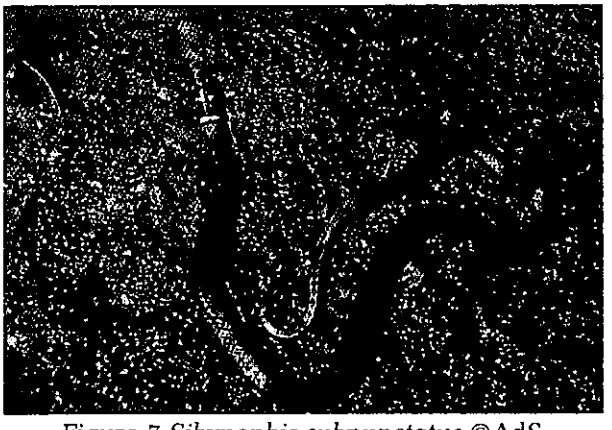


Figure 7 *Sibynophis subpunctatus* ©AdS

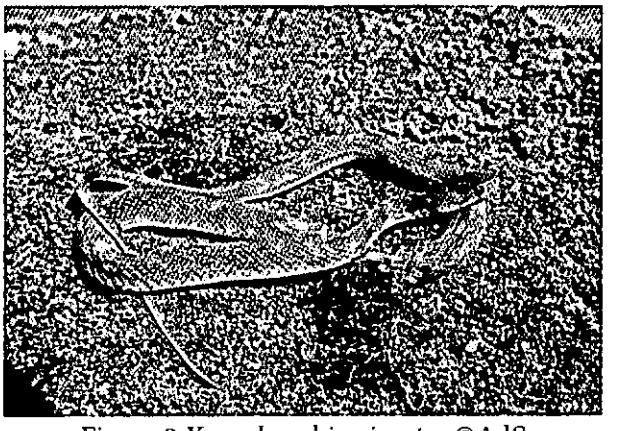


Figure 8 *Xenochrophis piscator* ©AdS

Plate R10 - Snakes 3

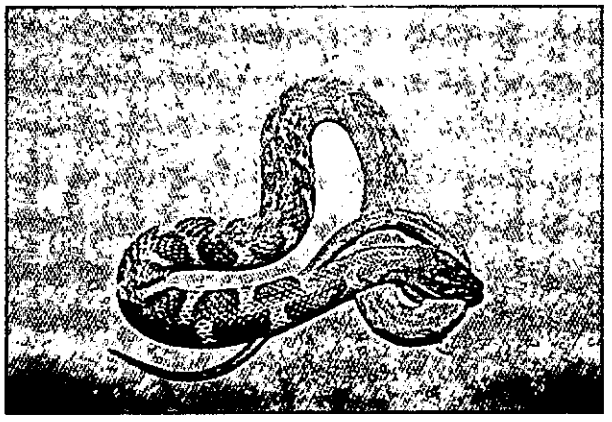


Figure 1 *Xenochrophis asperrimus* ©AdS

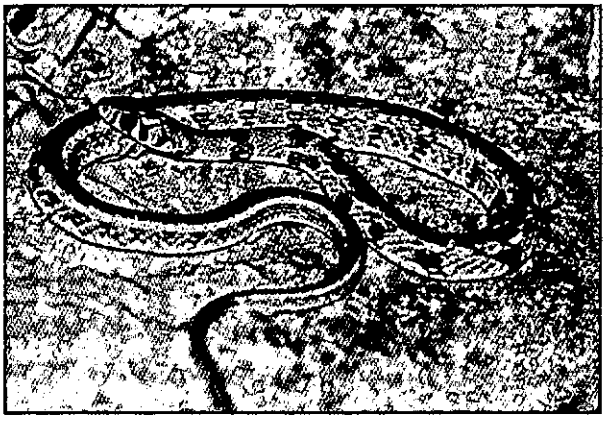


Figure 2 *Amphiesma stolatum* ©SG

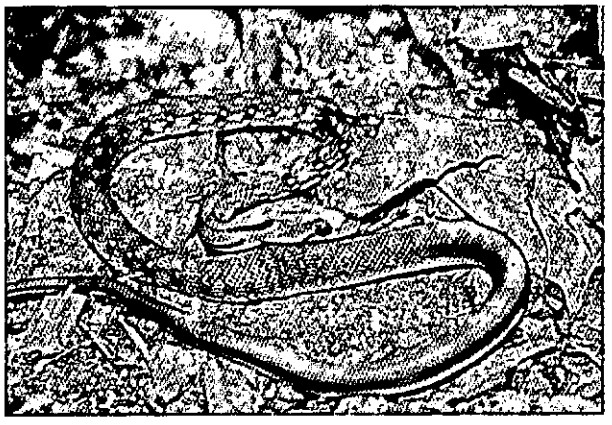


Figure 3 *Coelognathus helena* ©SG

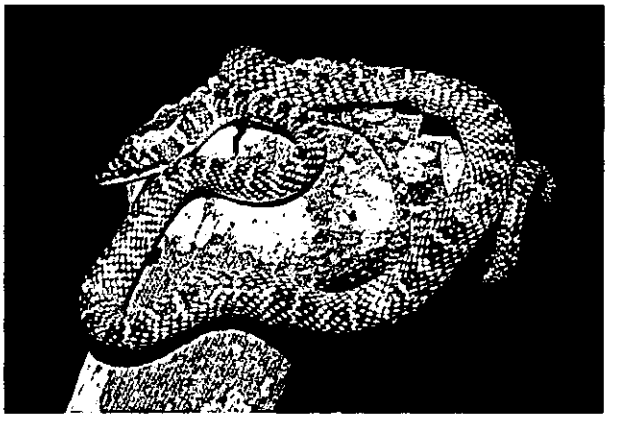


Figure 4 *Chrysopelea ornata ornata* ©AdS

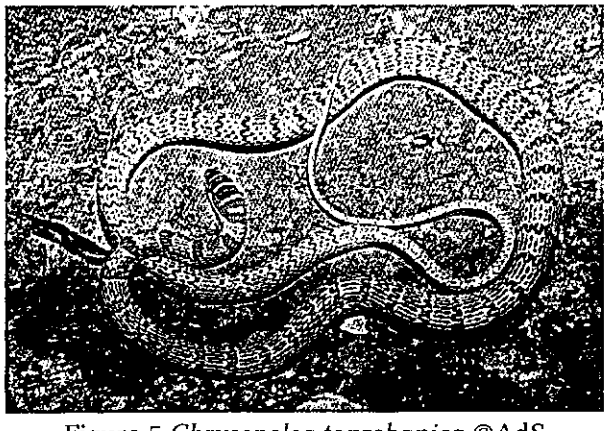


Figure 5 *Chrysopelea taprobanica* ©AdS

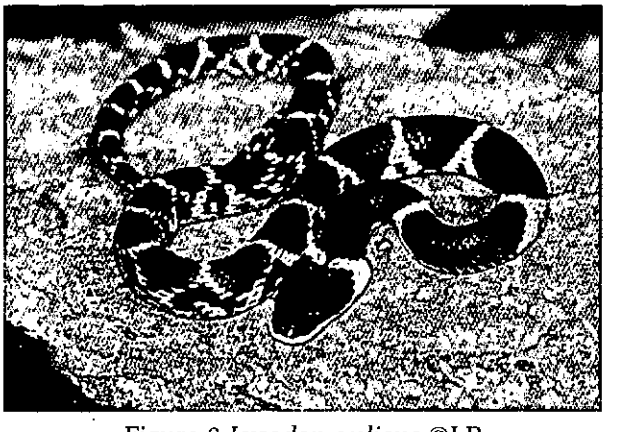


Figure 6 *Lycodon aulicus* ©LP

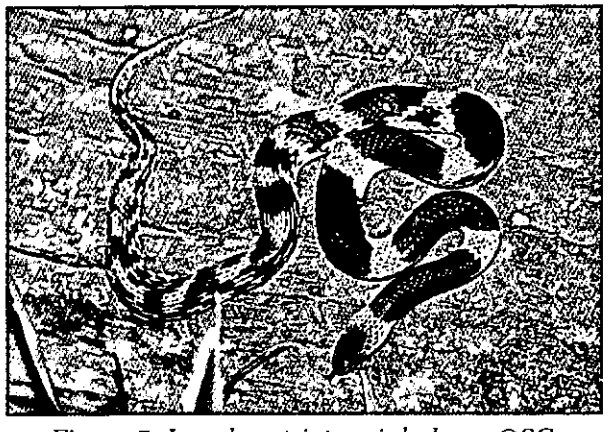


Figure 7 *Lycodon striatus sinhaleyus* ©SG

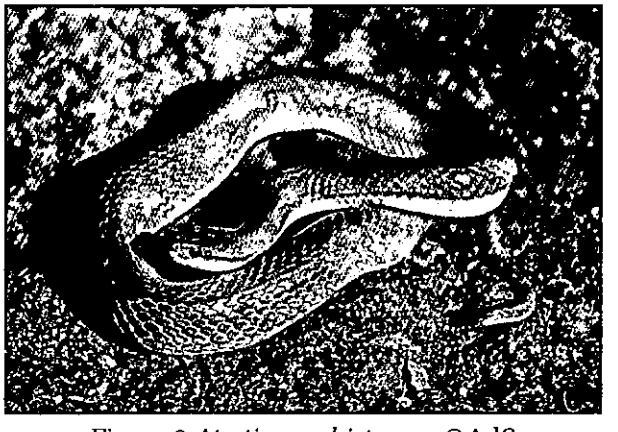


Figure 8 *Atretium schistosum* ©AdS

Plate R11 - Snakes 4

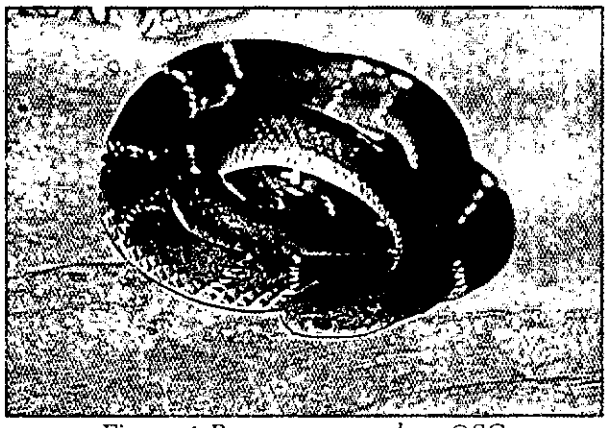


Figure 1 *Bungarus caeruleus* ©SG

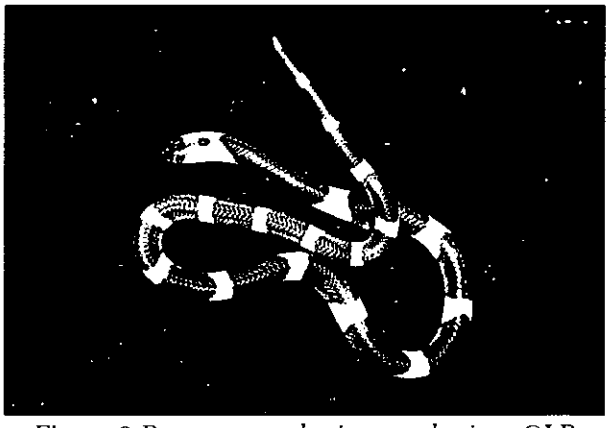


Figure 2 *Bungarus ceylonicus ceylonicus* ©LP

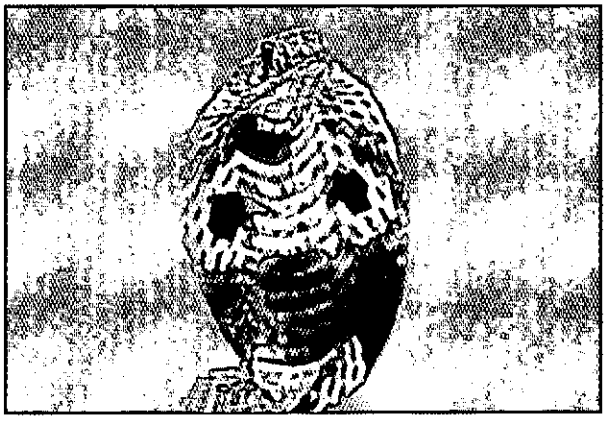


Figure 3 *Naja naja* ©AF

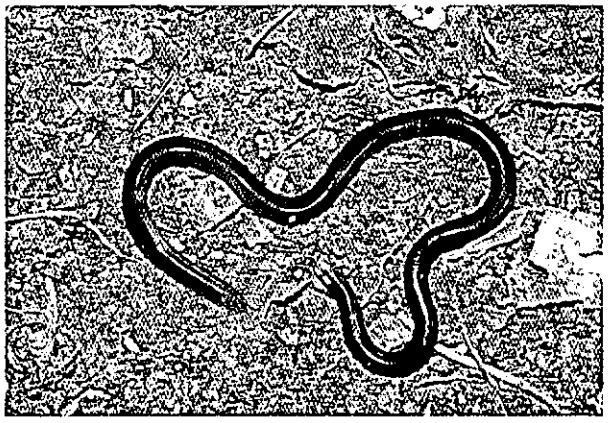


Figure 4 *Ramphotyphlops braminus* ©SG

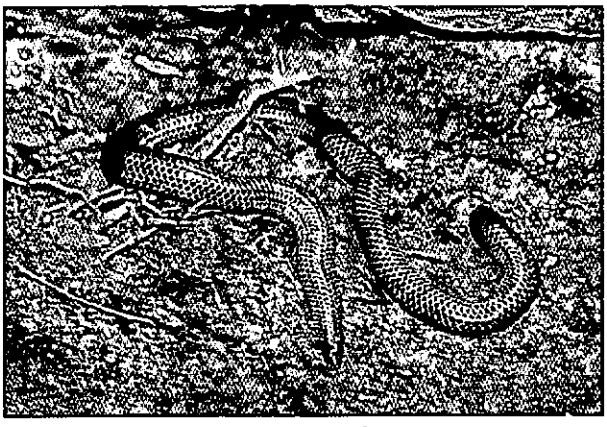


Figure 5 *Rhinophis philippinus* ©SG

Figure 6 *Pseudotyphlops philippinus* ©SG

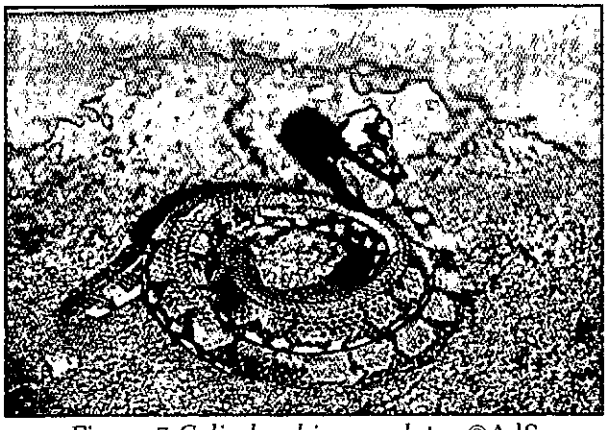


Figure 7 *Cylindrophis maculatus* ©AdS

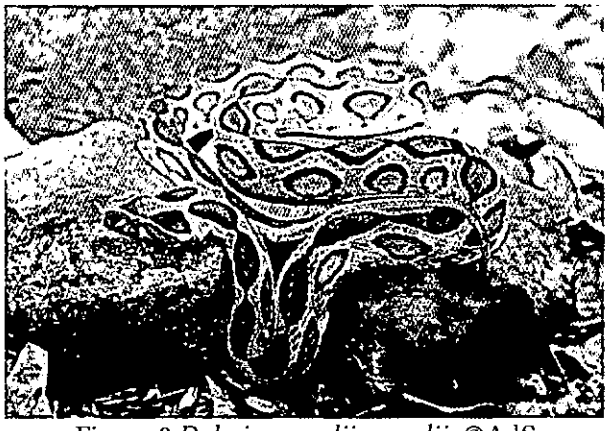


Figure 8 *Daboia russelii russelii* ©AdS

Chapter 7
Crocodiles, turtles and monitor lizards

Introduction
Two species of monitor lizards, two species of crocodile and four inland species of chelonians are known from Sri Lanka. Of these we observed the following during the Knuckles expeditions of 2004 and 2005.

Family Crocodylidae

Genus *Crocodylus*
***Crocodylus paluster* (Lesson, 1834)**
This species is known in English as the Mugger or Marsh crocodile, and Hala kimbula in Sinhalese.

Although we did not observe live crocodiles, signs of crocodile activity were noted on the banks of the Namini Oya reservoir (1.5 km from Hettipola) by the presence of several fresh skid marks (Plate R12 Figure 3) and characteristic white faeces. From the skid marks it was apparent that they had been left by medium sized specimens. The local residents living close to the tank have observed up to 6 specimens at a time when they emerge to bask during the morning and afternoon. As regards the species identification it is well know that only *Crocodylus paluster* or the Mugger inhabits lowland tanks. *Crocodylus paluster* has not been reported from the Knuckles area in previous reports (Ginige, 1994; Bambaradeniya & Ekanayake, 2003; Cooray, 1998).

Although the reservoir has been recently constructed, a no-fishing area has been declared which is good for species conservation. However, there is still potential for conflict between local residents and the conservation efforts because people tie cattle next to the tank, which could entice crocodiles. If a crocodile kills cattle it is likely that an unwelcome response would be invoked by local residents who may attempt to kill all of the crocodiles. Also the police too could shoot "nuisance crocodiles". There havealso been reports that people have been keeping hatchling crocodiles for ornamental purposes without knowing that it is illegal and that it is very difficult to keep such specimens in captivity. People in the area have also killed and eaten crocodile meat.

Crocodylus paluster is considered to be Vulnerable in the CAMP report, which assessed this reptile using IUCN Red List criteria A1acd, B1+2c, (de Silva *et al,* 2000). It is also listed as Threatened in the 1999 National list of threatened animals (IUCN, Sri Lanka, 2000).

Order Testudines
Family Trionychidae

Genus *Lissemys*
***Lissemys punctata punctata* (Bonnaterre, 1789)**
This species is known in English as the Soft shell or Flapshell turtle and in Sinhalese as the Kiri ibba
The flap-shell or soft-shell turtle is common in waterways around the Knuckles especially near human habitation and agriculture but not at high elevations (Plate R12 Figure 6). The flesh of the species is commonly eaten in the area. It is believed that it has medicinal properties and is referred to as the 'river chicken' due to a similarity in its meat to chicken in both properties and cooking style. The species has been eaten since ancient times – evident from discovering bone artefacts during archaeological excavations from sites dating from 800 - 500 BC (Chandraratne, 1997). As they scavenge on carrion people use baited fishing lines to catch them.

The species has previously been recorded from the Knuckles area (Ginige, 1994; Bambaradeniya and Ekanayake, 2003). Considered to be Vulnerable in the CAMP report, which assessed this reptile using IUCN Red List criteria A1c (de Silva *et al,* 2000) it is listed as Threatened in the 1999

National list of threatened animals (IUCN, Sri Lanka, 2000).

Family Bataguridae

Genus *Melanochelys*
Melanochelys trijuga thermalis
This species is known in English as the Spotted Black Turtle or Hard Shell terrapin and in Sinhalese as the Gal ibba.

It is commonly seen in man made waterways close to human habitation in buffer and transition zones but not at high elevations in the Knuckles (Plate R12 Figure 7). The flesh of this turtle is widely eaten by local inhabitants due to the belief that it increases the libido. There is evidence that it has been eaten since ancient times as well due to bones found in archaeological sites dating from 800 - 500 BC (Chandraratne, 1997). Due to being an omnivorous scavenger it is commonly caught accidentally by fishermen whose bait they have been attracted to. Thus people learnt by accident how to catch them using fishing lines and bait, which is now done purposefully.

The species was previously recorded from the Knuckles area (Ginige, 1994; Bambaradeniya and Ekanayake, 2003). It is not listed as Threatened in the 1999 National list of threatened animals (IUCN, Sri Lanka, 2000), as it is widespread throughout the country. It is also found in India.

Family Testudinidae

Genus *Geochelone* (Schoepff, 1795)
***Geochelone elegans* (Schoepff, 1795)**
This species is known in English as the Star tortoise and in Sinhalese as the Tharaka ibba.

Five specimens were observed during the study (4 adults, 1 juvenile), while crossing roads or at the roadside and near agricultural land in buffer and transition zones but not at high elevations in northern and eastern parts of the Knuckles (Plate R12 Figure 8). We were informed that occasionally local inhabitants eat the flesh of the star tortoise. Shell necrosis was observed in certain specimens and ticks were recorded near rear legs. These conditions have been previously well documented (de Silva, 2003). The species is threatened due to collection for the pet trade and grievous injuries caused during agricultural activities (de Silva, 2003).

The Star tortoise was not previously recorded in the Knuckles area. It is considered Vulnerable in the CAMP report, which assessed the reptile using IUCN Red List criteria A1cd (de Silva *et al*, 2000). It is listed as Threatened in the 1999 National list of threatened animals (IUCN, Sri Lanka, 2000).

Family Varanidae

Genus *Varanus* (Gray, 1827)
***Varanus bengalensis* (Daudin, 1802)**
This species is known in English as the Land Monitor lizard and in Sinhalese as the Tala goya.

Varanus bengalensis was observed in Kobonilla (1191m) – the highest elevation possibly recorded for the species in Sri Lanka. It was seen more commonly throughout the Dry Zone area than throughout the Wet zone area of the Knuckles, spanning from the south east to the north east and north west of the range (Plate R12 Figure 4). We were informed that the residents of the Knuckles eat the flesh of Land Monitor lizards killed by road traffic.

The species has been previously recorded in the Knuckles area (Ginige, 1994; Bambaradeniya and Ekanayake, 2003). Considered to be at Low risk in the CAMP report, which assessed this reptile using IUCN Red List criteria (de Silva *et al*, 2000) it is not listed as Threatened in the 1999 National list of threatened animals (IUCN, Sri Lanka, 2000).

***Varanus salvator* (Laurenti, 1768)**
This species is known in English as the Water Monitor lizard and in Sinhalese as the Kabara goya.

It is commonly seen in man made

waterways close to human habitation in buffer and transition zones but not at high elevations in the Knuckles (Plate R12 Figure 5). They are not eaten by local residents as they believe the species to be highly poisonous. It was reported that road kills were common on the Hettipola road. Traffic induced injuries were observed by the project.

The species has previously been recorded from the Knuckles area (Ginige, 1994; Bambaradeniya and Ekanayake, 2003). Considered to be at Low risk in the CAMP report, which assessed the reptile using IUCN Red List criteria (de Silva *et al*, 2000) it is not listed as Threatened in the 1999 National list of threatened animals (IUCN, Sri Lanka, 2000).

Plate R12 - Snakes & other reptiles

Figure 1 *Hypnale nepa* ©SG

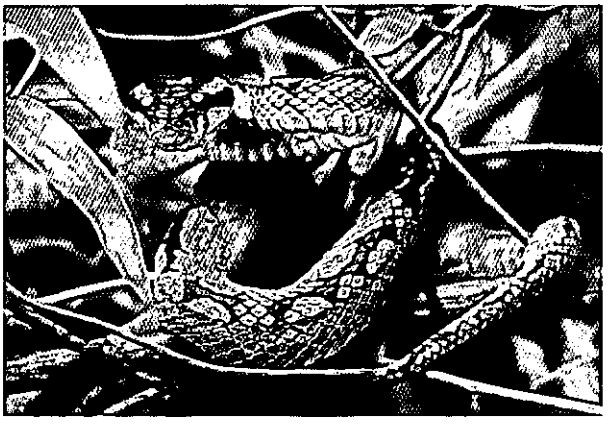


Figure 2 *Trimeresurus trigonocephalus* ©SG

Figure 3 Foot prints of *Crocodylus paluster* ©JD

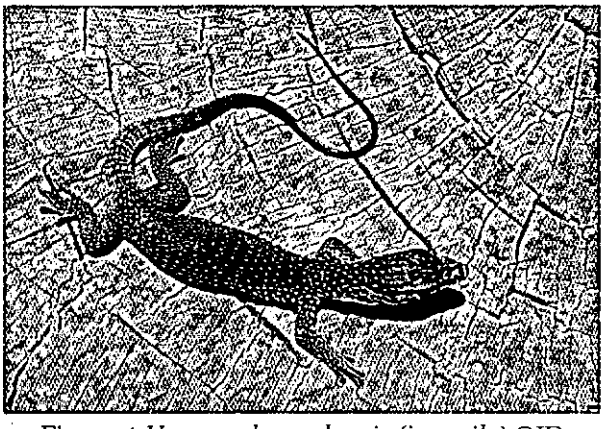


Figure 4 *Varanus bengalensis (juvenile)* ©JD

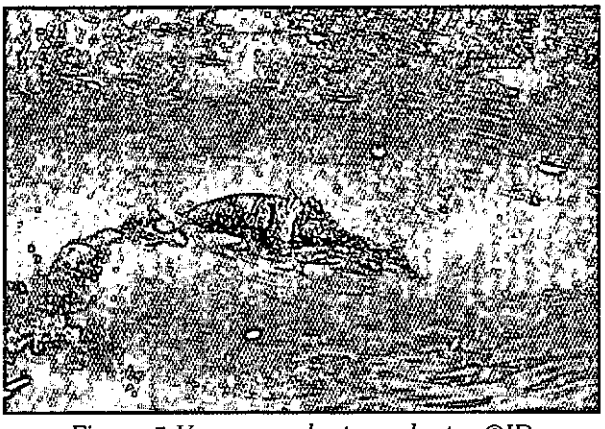


Figure 5 *Varanus salvator salvator* ©JD

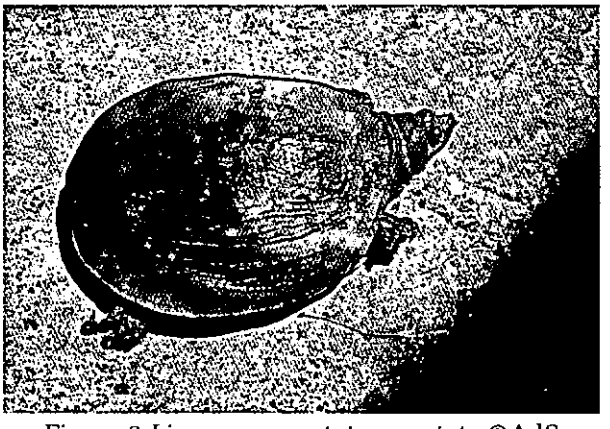


Figure 6 *Lissemys punctata punctata* ©AdS

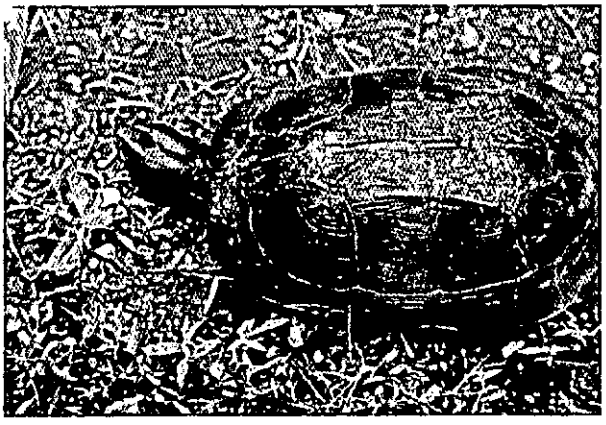


Figure 7 *Melanochelys trijuga thermalis* ©AF

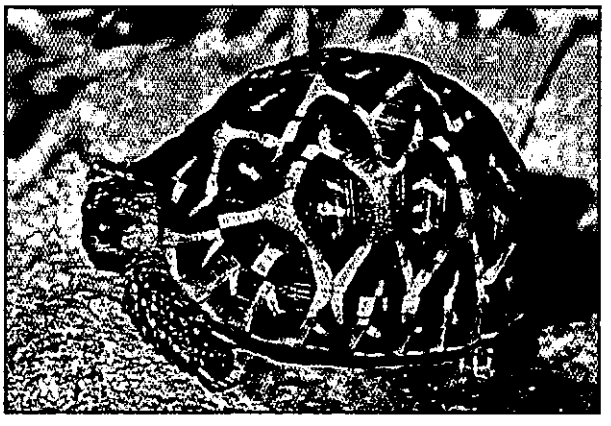


Figure 8 *Geochelone elegans* ©SG

Chapter 8
Amphibians

The amphibian diversity of Sri Lanka is extremely high. The country has the highest amphibian species per unit area of land in the world (3.9 per 1,000 km^2) (Pethiyagoda and Manamendra-Arachchi 1998; Manamendra-Arachchi & Pethiyagoda 2005). Wildlife Heritage Trust (WHT) work on amphibian systematics which is currently in progress will hopefully reveal more interesting details in the future. Current literature documents 103 extant and extinct amphibian species from Sri Lanka (Dutta & Manamendra-Arachchi 1996; de Silva 2001; Bossuyt & Dubois 2001; Manamendra-Arachchi & Pethiyagoda 2005 and Meegaskumbura & Manamendra-Arachchi 2005). Ongoing studies show that even this was a gross underestimate, and that the true figure may be as high as 250 species (Pethiyagoda and Manamendra-Arachchi 1998). The recent description of five new amphibian species from a mere 10-50 km^2 forest at Corbett's Gap (1240m) in the Knuckles indicates this as a distinct possibility (Manamendra-Arachchi & Pethiyagoda 2005; Meegaskumbura & Manamendra-Arachchi 2005). Recent studies using molecular phylogenies have shown that Sri Lanka has maintained an amphibian fauna that is distinct from that of the Western Ghats of India (Bossuyt *et al.*, 2004).

Four earlier papers written on the Knuckles included lists of amphibian species the particular authors had observed in the area's ecosystems: 20 species by the IUCN and Forestry Department (1994); 16 species by Rathnayake *et al.*, (1999); 20 species by Rathnayake (2001) and 20 species by Bambaradeniya & Ekanayake (2003). However, the validity of some of the amphibian species listed in these papers need verification.

For further discussion on individual amphibian species as well as the threats they were observed to face during the Knuckles expeditions of 2004 and 2005, see de Silva *et al.*, (2005o). The species encountered have been listed to show the diversity in the Knuckles. It is important to note that a few amphibians could not be identified using the available keys and can thus be considered as new species (personal communication, Manamendra-Arachchi, 2005). Sri Lanka has recorded 19 amphibian extinctions, one of the highest rates in the world (Stuart *et al.*, 2004, Manamendra-Arachchi & Pethiyagoda, 2005)

The following species were observed during the project. For further details see De Silva *et al.*, (2005o)for additional ecological notes on some of these species.

NB- IUCN Red List Category is based on Global Amphibian Assessment (IUCN, 2004), unless otherwise stated.

FAMILY: BUFONIDAE Gray, 1825

Genus: *Adenomus* Cope, 1860

1. *Adenomus kelaartii* Günther, "1858", 1859
Kelaart's smooth finger toad, or Kelartge siniduangili gemba is an endemic species with an IUCN Red List Category of Endangered under Criteria B1ab(iii) +2ab(iii) (Plate 11 Figure 1).

Genus: Bufo Laurenti, 1768

2. *Bufo melanostictus* Schneider, 1799
The House toad or Geyi gemba a non endemic species with an IUCN Red List Category of Least Concern.

FAMILY: MICROHYLIDAE Günther, 1858

Genus: *Kaloula* Gray, 1831

3. *Kaloula taprobanica* Parker, 1934
The Common Bull frog or Visituru rathu madiya is a non-endemic species with an IUCN Red List Category of Least Concern (Plate R13 Figure 1).

Genus: *Microhyla* Tschudi, 1838

4. *Microhyla ornata* Dumeril and Bibron, 1841

The Ornate Narrow Mouth frog or Visituru muvapatu madiya is a non endemic species with an IUCN Red List Category of Least Concern (Plate R13 Figure 2).

Genus: *Ramanella* Rao and Ramanna, 1925

5. *Ramanella obscura* Günther, 1864

The Grey-brown Pug-snout frog or Alu Dumburu Motahombu madiya is an endemic species with an IUCN Red List Category of Near Threatened (Plate R13 Figure 3).

6. *Ramanella variegata* Stoliczka, 1872

The White-bellied Pug-snout frog or Badasudu Motahombu madiya is a non endemic species with an IUCN Red List Category of Least Concern.

FAMILY: RANIDAE Rafinesque-Schmaltz, 1814

Genus: *Lankanectes* Dubois & Ohler, 2001

7. *Lankanectes corrugatus* Peters, 1863

The Corrugated frog or Vakarali madiya is an endemic species with an IUCN Red List Category of Least Concern (Plate 11 Figure 2).

Genus: *Euphlyctis* Fitzinger, 1843

8. *Euphlyctis cyanophlyctis* Schneider, 1799

The Skipper frog or Utpatana madiya is a non endemic species with an IUCN Red List Category of Least Concern.

9. *Euphlyctis hexadactylus* Lesson, 1834

The Six-toed Green frog or Sayangili palamadiya is a non endemic species with an IUCN Red List Category of Least Concern.

Genus: *Fejervarya* Bolkay, 1915

10. *Fejervarya kirtisinghei* Manamendra-Arachchi & Gabadage, 1996

Kirtisinghe's Grass frog or Kirtisinghage Thruna madiya is an endemic species with an IUCN Red List Category of Least Concern.

11. *Fejervarya limnocharis* Boie, 1835

The Common Paddy Field frog or Vel madiya is a non endemic species with an IUCN Red List Category of Least Concern.

Genus: *Nannophrys* Günther, 1869

12. *Nannophrys marmorata* Kirtisinghe, 1946

Kirtisinghe's rock frog or Kirtisinghege galpara madiya is an endemic species with an IUCN Red List Category of Critically Endangered under Criteria B1ab(iii) (Plate 11 Figure 3).

Notes: *Nannophrys marmorata* is mainly confined to the Knuckles.

Genus: *Rana* Linnaeus, 1758

13. *Rana gracilis* Gravenhorst, 1829

The Sri Lanka Wood frog or Lanka Badi madiya is an endemic species with an IUCN Red List Category of Least Concern.

14. *Rana temporalis* Günther, 1864

The Common Wood frog or Samaniya Badi madiya is a non endemic species with an IUCN Red List Category of Near Threatened (Plate R13 Figure 4).

Genus: *Sphaeroteca*

15. *Sphaeroteca breviceps* Schneider, 1799

The Band Sand frog or Tunhiri Vali madiya is a non endemic species with an IUCN Red List Category of Least Concern.

16. *Sphaeroteca rolandae* Dubois, 1983

The Marble Sand frog or Lapavan Vali madiya is a non endemic species with an IUCN Red List Category of Least Concern.

SUBFAMILY: RHACOPHORINAE Hoffman, 1932

17. *Philautus cavirostris* Günther, 1869

The Tubercled Oriental Shrub frog or Hirigadu Gas madiya is an endemic species with an IUCN Red List Category of Endangered under Criteria B1ab(iii) (Manamendra-Arachchi & Pethiyagoda, 2005)(Plate R13 Figure 5).

18. *Philautus fergusonianus* Ahl, 1927

Ferguson's Oriental Shrub frog or Fergusonge Gas madiya is an endemic species with an IUCN Red List Category of Least Concern (Manamendra-Arachchi & Pethiyagoda, 2005).

19. *Philautus fulvus* Manamendra-Arachchi & Pethiyagoda, 2005
The Oriental Shrub frog or Gas madiya is an endemic species with an IUCN Red List Category of Endangered under Criteria B1ab(iii) (Manamendra-Arachchi & Pethiyagoda, 2005) (Plate 11 Figure 4).

20. *Philautus macropus* Günther, 1869
The Tree frog or Gas madiya is an endemic Species with an IUCN Red List Category of Critically Endangered under Criteria B1ab(iii) (Manamendra-Arachchi & Pethiyagoda, 2005) (Plate 11 Figure 5).

21. *Philautus steineri* Meegaskumbura & Manamendra-Arachchi, 2005
The Oriental Shrub frog, also known as the Gas madiya is an endemic species with an IUCN Red List Category of Endangered under Criteria B1ab(iii) (Meegaskumbura & Manamendra-Arachchi, 2005) (Plate 11 Figure 6).

22. *Philautus stuarti* Meegaskumbura & Manamendra-Arachchi, 2005
The Oriental Shrub frog, also known as the Gas madiya is an endemic species with an IUCN Red List Category of Endangered under Criteria B1ab(iii) (Meegaskumbura & Manamendra-Arachchi, 2005) (Plate 11 Figure 7).

23. *Philautus* species (possible new species) 1 (Plate R13 Figure 6).

24. *Philautus* species (possible new species) 2 (Plate R13 Figure 7).

25. *Philautus* species (possible new species) 3 (Plate R13 Figure 8).

SUBFAMILY: RHACOPHORINAE Hoffman, 1932
Genus: Polypedates Tschudi, 1838
26. *Polypedates cruciger* Blyth, 1852
The Common Hour-glass Tree-frog or Sulaba Pahimbu Gas madiya is an endemic species with an IUCN Red List Category of Least Concern.

27. *Polypedates eques* Günther, 1858 (publ.1859)
The Saddle Tree frog or Mukalan Pahimbu Gas madiya is an endemic species with an IUCN Red List Category of Endangered under Criteria B1ab(iii)

28. *Polypedates maculatus* Gray, 1834
The Chunam Tree frog or Hunu-gomara Gas madiya is a non endemic species with an IUCN Red List Category of Least Concern.

FAMILY: ICHTHYOPHIIDAE Taylor, 1968

Genus: *Ichthyophis* Fitzinger, 1826
29. *Ichthyophis glutinosus* Linnaeus, 1758
The Common Yellow Band caecilian or Kaha hiridanda is an endemic species with an IUCN Red List Category of Least Concern (Plate 11 Figure 8).

Threats

Some specific threats to amphibians were observed in the Knuckles during the study. These may threaten some of the species that are mainly confined to Knuckles with extinction. It was observed that *Adenomus kelaartii, Nannophrys marmorata* and *Lankanectes corrugatus* were not as common as reported by earlier surveys (Bambaradeniya and Ekanayake, 2003). A possible reason for this may be the wide use of agrochemicals (pesticides and fertilizer) by farmers working on land occupied by these relict species. The above species being mostly found in highly fragmented localities is also a cause for concern. The populations of the recently described amphibian species *Philatus fulvus, P. mooreorum, P. hoffmanni, P. sterneri* and *P. stuarti* (Manamendra-Arachchi & Pethiyagoda, 2005; Meegaskumbura and Manamendra-Arachchi, 2005) inhabit areas of less than 50 km^2 of the Knuckles. As the populations of these habitat specialist species are small, any impact on their dispersed habitats can potentially lead to their extinction.

Threats and conservation aspects are discussed in detail in Chapter 10 in the present monograph. For discussion on threats and recommendations with particular reference to *Adenomus kelaartii, Nannophrys marmorata* and *Lankanectes corrugatus* see De Silva *et al.*, (2005o).

Plate R13 - Amphibians

Figure *1 Kaloula taprobanica* ©AdS

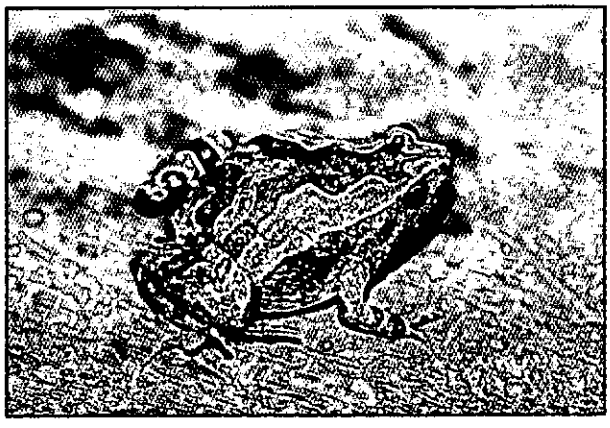


Figure 2 *Microhyla ornata* ©SG

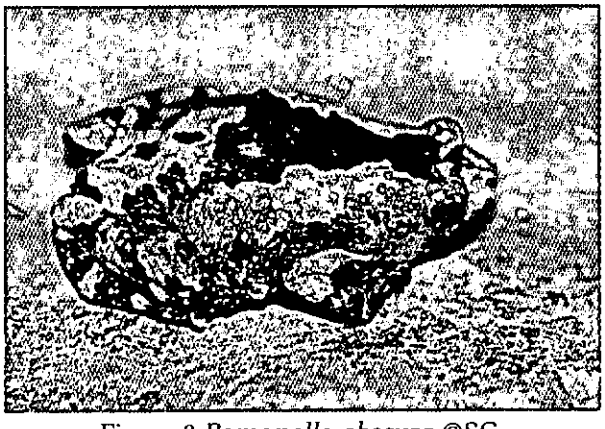


Figure 3 *Ramanella obscura* ©SG

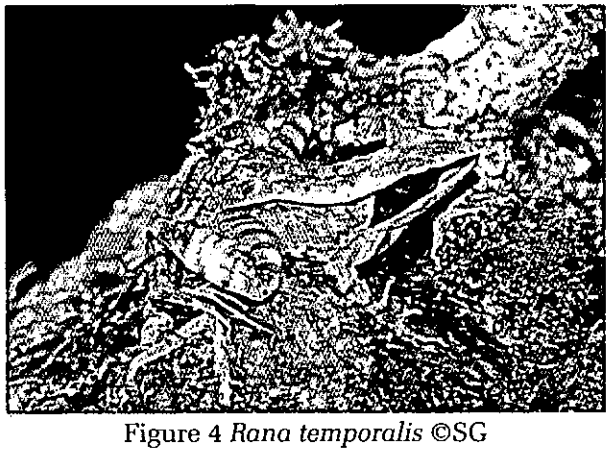


Figure 4 *Rana temporalis* ©SG

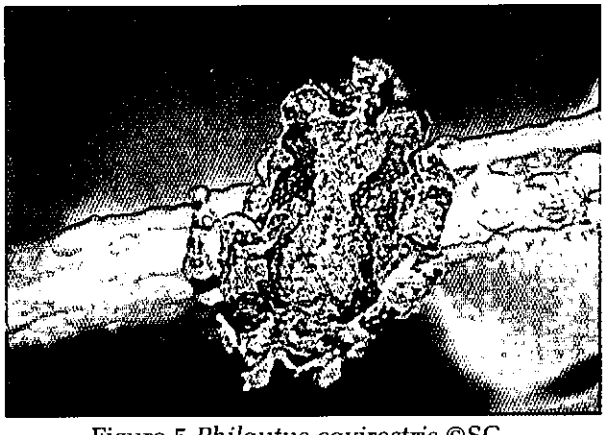


Figure 5 *Philautus cavirostris* ©SG

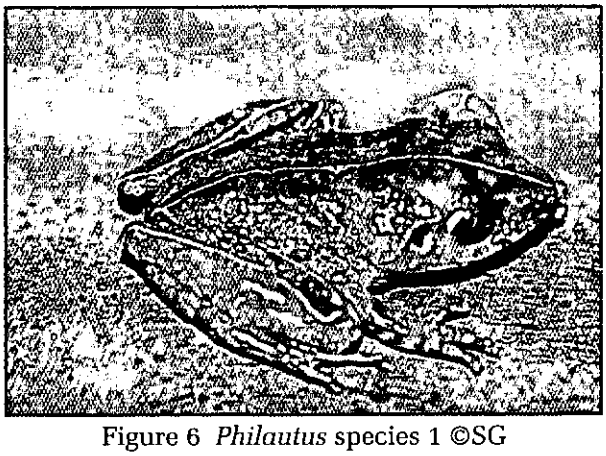


Figure 6 *Philautus* species 1 ©SG

Figure 7 *Philautus* species 2 ©SG

Figure 8 *Philautus* species 3 ©SG

Chapter 9
Other vertebrates and invertebrates

Introduction

Knuckles region with its high vegetation, climate and altitudinal variations is home for many vertebrate and invertebrate species. We observed the following in the Knuckles region during the expeditions in 2004 and 2005.

Bird diversity

A great many birds live in and around the Knuckles forest. Some are migrants whilst others remain all year round. The IUCN (Bambaradeniya and Ekanayake, 2003) has recorded 128 species of birds belonging to the following Famalies (*Ardeidae, Phalacrocoracidae, Ciconidae, Threkiornithidae, Accipitridae, Phasianidae, Rallidae, Charadriidae, Scolopacidae, Columbidae, Psittiacidae, Cuculidae, Strigidae, Caprimulgidae, Podargidae, Apodidae, Hemiprocnidae, Trogonidae, Alcedinidae, Meropidae, Bucerotidae, Capitonidae, Picidae, Pittidae, Hirundinidae, Motacillidae, Campephagidae, Pycnonotidae, Irenidae, Laniida, Turdidae, Timaaliidae, Sylviidae, Muscicapidae, Monarchidae, Paridae, Dicaeidae, Nectariniidae, Zosteropidae, Estrildidae, Sturnidae, Oriolidae, Dicruidae, Corvidae* and *Sittidae*). Which included 17 of the 23 endemic birds of Sri Lanka and also included 20 species which were nationally threatened. .Project Knuckles has observed a 23 species, see De Silva *et al.*, 2005a.

Fish Diversity

IUCN (Bambaradeniya and Ekanayake, 2003) recorded 15 species of Freshawater fishes belonging to the following Famalies (*Cyprinidae, Cobitidae, Balitoridae* and *Clariidae*), although it is stated that the literature suggests the total is closer to 25 species. 8 species were found to be endemic and of which 7 species were nationally threatened. It is important to note that *Garra phillipsii, Pintius srilankensis* and *Pintius martenstyni* are endemics restricted to the Knuckles Range. These rare fish have evolved to specialise in certain portions of the stream.

Mammal Diversity

In addition to a high reptile and amphibian diversity, the Knuckles Mountains plays host to a number of other animal species. During the 2003 IUCN survey of the region, 247 vertebrate animals were recorded. 26% of these were endemic and 28% were nationally threatened. This shows both the richness of animal diversity in the region and the critical background of many of the species living in the country.

A healthy mammal population also inhabits the Knuckles region. The IUCN has documented 31, including four endemic species and nine nationally threatened species. Project Knuckles has observed a 23 of these, with the notable exception of the elusive Slender Loris (*Loris tardugradus*), Fishing cat (*Prionailurus viverinus*), Leopard (*Panthera pardus*), mongoose (*Herpestes fuscus*), wild boar (*Sus scrofa*), jackal (*Canis aureus*) and even the occasional elephant (*Elephas maximus*) have been sighted by the project. See De Silva *et al.*, 2005a for full list of mammals encountered during the study.

Leopard were spotted occasionally during the evening when the team was returning from fieldwork or driving to nearby Hunnasgiriya for supplies. Local residents traveling along the Loolwatte - Hunnasgiriya road frequently reported seeing leopard on the road during the early evening. Some pug marks seen on field work in Kobonilagala (Plate R14 Figure 1). There were several attacks on goats kept by estate laborers by leopard. In one instance 6 goats had been taken in one single day.

Elephants were hunted out in the Knuckles during the colonial period (Werner, 1982). However, they have been observed wandering into the north and eastern portions of the range from the neighbouring national park of Wasgamuwa. Dung was

found with large amounts of plastic near Namini Oya near Hettipola (Plate R14 Figure 2). Once when returning from Hettipola we along with students during Knuckles 2005 we observed a heard of 5 close to Pitawala Pathana during the day around 12 noon grazing in a open portion. Also several elephant dung was observed at Pitawala Pathanka (alt. 1000 m).

Invertebrates diversity

The main constituent part of the diet of birds, amphibians and reptiles is the large and diverse stock of invertebrates inhabiting the Knuckles Mountains. Over half of the described species of the world can be found living in tropical forests, and many more await scientific description. There is a massive arthropod diversity in tropical forests, with single trees hosting large numbers of different species (Weerakoon, 2002). The Knuckles forest is no exception and is filled with a variety of beetles, flies, spiders, scorpions, butterflies and dragonflies.

Over half of the described species of the world can be found living in tropical forests, and many more await scientific description. There is a massive arthropod diversity in tropical forests, with single trees hosting large numbers of different species. IUCN (Bambaradeniya and Ekanayake, 2003) recorded 60 species of Butterfies belonging to the following Famalies (*Lycaenidae, Riodinidae, Satyridae, Danaidae, Nymphalidae, Pieridae* and *Papilionidae*). 8 species were nationally threatened and of which 5 species were found to be endemic.

Mollusk diversity

The Knuckles range of mountains or the Dumbara hills is the home for several species of mollusks. Approximately 37 species are known from the Knuckles (Ranawana, 2005). Approximately 246 species of land snails are known in Sri Lanka, of which the majority (83%) are endemic (Naggs and Raheem, 2000).

During the study a survey was carried out to see the diversity of the snail diversity, as well as to assess and identify the threats faced by this group of invertebrates and their habitats. Snail iidentification was based on Naggs and Raheem (2003) and during the investigations 25 species of mollusks were located and identified of which 13(52%)species were endemic, see De Silva *et al.*, (2005q) for further details of the findings.

Plate R14 - Other fauna

Figure 1 *Panthera pardus kotiya* pug marks ©SG

Figure 2 *Elephas maximus maximus* dung with plastic ©SG

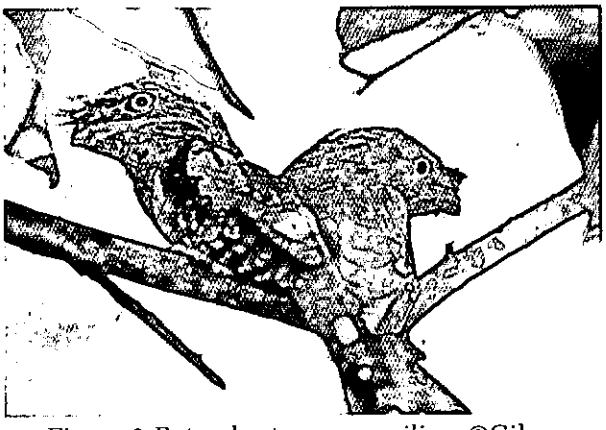


Figure 3 *Batrachostomus moniliger* ©Gihan

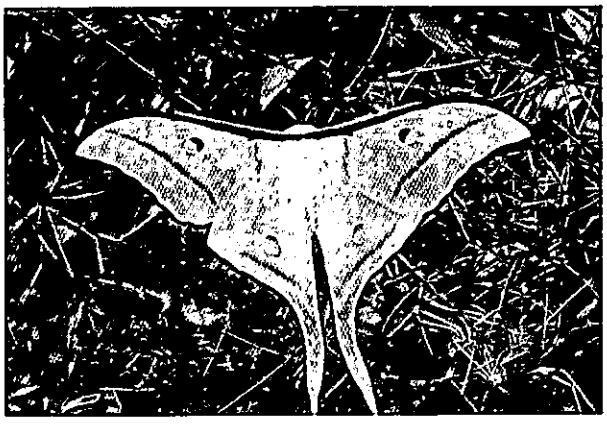


Figure 4 Indian Moon Moth - *Actias selene* ©SG

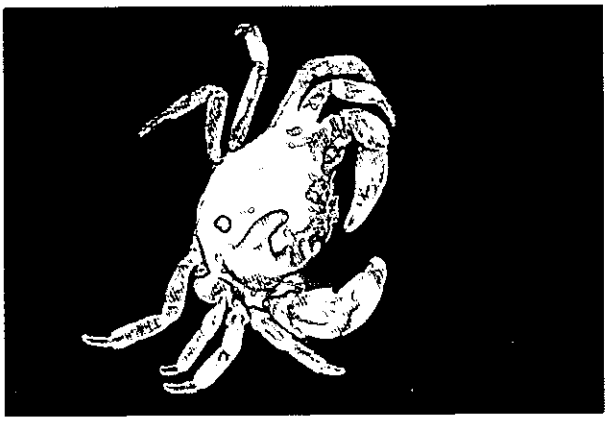


Figure 5 Crab species ©LP

Figure 6 *Poecilotheria fasciata* ©SG

Figure 7 Stick Insect ©SG

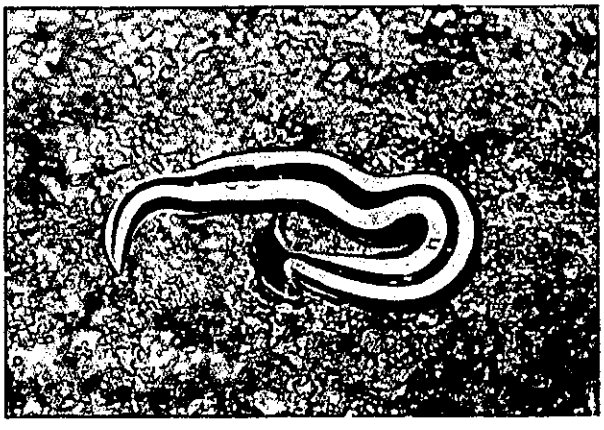


Figure 8 Flat worm ©SG

Chapter 10
Threats, Conservation and Recommendations

Introduction

Earth's most striking feature is its biodiversity (Tilman, 2000), which can be defined as "the sum total of all biotic variation from the level of genes to ecosystems" (Purvis and Hector, 2000). We are currently in the 6th major extinction event of global history, and it has been "triggered" by human activity (Chapin *et al.*, 2000).

Threats

The fragile ecosystems found throughout the Knuckles Mountains are faced with many threats. Some of these could be easily remedied through co-operative action between the relevant government departments and the residents of the Knuckles region. However, other threats are more widespread, even global, and require extensive research, efforts and resources to combat them. We wish to discuss the following threats, which were observed during the Knuckles study of 2004 and 2005.

Habitat Loss, Degradation & Fragmentation

The biggest threats facing the herpetofauna of the Knuckles include habitat loss through deforestation (Plate R15 Figure 1), habitat alteration and habitat fragmentation (Plate R15 Figure 2), which are caused during the establishment of plantations and settlements. Vast tracts of primary forest up to altitudes of over 1000m were first cleared in the mid 19th century for the cultivation of coffee and tea. However, despite the failure of coffee, and gradual reduction in the production of tea in the Knuckles, large-scale agricultural practices continue in the area. Despite land above the 1067 m contour line being currently designated as a conservation area, the forest here continues to suffer damage. The cultivation of cardamom (*Ellettaria cardamomum*) in the area increased considerably from the 1960s until the recent ban. This type of cultivation requires that the farmer clear the under storey and many trees in a forest, leaving only a select few trees to provide shade and shelter for the cardamom. The negative impacts of cardamom cultivation in the Knuckles have been extensively reported (Abeygunawardena & Vincent 1993; Gunawardane 2003). Studies have shown that in natural forested areas without cardamom cultivation the 'A' horizon or uppermost layer of soil is well preserved and covered with mulch to a depth of 30-35cm whilst in cardamom fields the mulch level has been reduced to 15-25cm (Madduma Bandara, 1991). However, when we measured the mulch level in many types of forests and plantations during the survey in 2004 and 2005, it was less than 10 cm. Incidences of soil erosion were high (Plate 1 Figure 8). We can thus foresee long-term, irreversible habitat degradation that could negatively impact upon many animals that live in the humus of the forest floor. The presence of this humus affects the levels of soil moisture and the resulting cooler temperatures, both of which are important habitat requirements for fossorial and sub-fossorial species, as well as many amphibians which lay their eggs in the leaf litter or humus on the forest floor. The loss of soil humus and moisture is drastically reducing the habitat quality of endangered fossorial and sub-fossorial species such as *Chalcidoseps thwaitesii* and *Nessia bipes*. It was observed that when *C. thwaitesii* specimens were removed from their niche for 10 to 15 minutes their skin started to dry and eventually shrivel. Thus, the coolness, moisture and humus layer of *C. thwaitesii* microhabitat appear to be critical factors for the survival of the species.

In order to become a high value product, cardamom must first be dried, a process, which requires fire. As wood is the region's primary source of maintaining a fire, many local tree species are felled to keep up with demand. Although there seems to have been a reduction in the number of drying 'barns', the few still in operation remain stocked with wood collected both legitimately and illegally from the forest.The Knuckles forests are highly

fragmented, in particular, the Upper and Lower Montane forests (Plate R15 Figure 2). Species populations here are isolated and concentrated into islands, whereby all the associated problems such as inbreeding and vulnerability to forest fire are heightened. However, research remains too minimal to state how much of a threat this poses to the species.

If reserves become remnants of natural habitat surrounded by alien habitats such as crop land or pasture, changes brought about by isolation and exposure have implications for the persistence of species within them. Changes in fluxes of wind, water and solar radiation can lead, in turn, to changes in vegetation structure, micro-climate, ground cover and nutrient status of habitat soils (USOT Assessment 1993). These changes may favour some species, but they also lead to reduced population sizes and local extinctions of others (Jones, *et al., 1998;* Fisher and Hanermann, *1986*). Firstly, the species inhabiting these fragments are restricted in terms of breeding partners and inbreeding can become a serious problem in smaller fragments. Once isolated and exposed, habitat remnants may be placed on a trajectory of continued change. Deleterious effects can feed back on themselves to increase their magnitude, or they can simply accumulate with time, or else they can cascade, with a change in a species' abundance or productivity leading to unforeseen changes in the populations of other species. In fragmented landscapes, where reserves are likely to be small and isolated, targets for off-reserve conservation are particularly important and they should include buffers around remnants, sympathetic management of poorly protected vegetation types or environments and habitat restoration (Margules and Pressey, 2000).

As a result of habitat loss, many forest species have adjusted themselves to live in home gardens near the forest edge where there is an increased risk of predation by domestic animals such as cats and poultry. Reptiles such as the agamid *Lyriocephalus scutatus*, snakes and skinks are left over exposed to predators such as the coucal (*Centropus sinensis*) and the crested serpent eagle (*Spilornis cheela*) (Bambaradeniya *et al.*,1997; Manamendra-Arachchi and Liyanage, 1994; de Silva, 1996).

Human disturbance and Agriculture

Chapin *et al.*, (2000) considered land use change would have the biggest effect on biodiversity by 2100, followed by climate change. Recent forestry legislation has stipulated that cardamom cultivation above 1067m should be terminated in the Knuckles region. As a result, many of the cardamom plantations have been abandoned. The move was intended to help conserve the forest and its inhabitants but the process of simply abandoning cardamom plantations has had the opposite effect. "Cardamom cultivation discourages the growth of new generations of plants" (Ramakrishnan and Navaratne, 1991) and thus inhibits natural regeneration. The simplification of ecosystems through agriculture makes the system more vulnerable to invasions (McCann, 2000). Ecosystems have been shown to be less stable when they have lower biodiversity (Tilman, 2000). This has allowed for exotic and invasive species to replace both the cardamom and any prospective forest tree saplings before they have the chance to develop into mature trees. It is possible that abandoned cardamom plantations could develop into scrub vegetation, completely altered and grossly different from the pristine habitat which once stood in its place. Whilst this may be catastrophic for the area's flora, we observed *C. tennentii* individuals inhabiting scrub forest (Plate R3 Figure 5) pine plantations and amongst plant species such as *Lantana camara*, indicating that they may not be directly affected by such changes in flora. However, the long-term implications of such microhabitat alterations are not yet clear.

Globalisation gives rise to invasive species due to human movements and transportation (Lodge, 1993; Cohen and Carlton, 1998). Even in protected areas, native species are often out-competed by exotics (Chapin, et al., 2000). Reforestation programmes have frequently been found to be sterile monocultures which support little biodiversity (Manamendra-Arachchi and

Liyanage, 1994). Furthermore, simple ecosystems are vulnerable to invasion (Elton, 1958).This has been demonstrated in the Knuckles by the increase in the number of alien invasive weed species such as Lantana (*Lantana camara*) and Mistflower (*Eupatorium reparium)* (Plate R15 Figure 3). The latter was first imported to the Hakgala Botanical gardens in 1900 and subsequently spread throughout the central hills. This weed has now spread to the Knuckles and is widely distributed throughout many of the ecosystems. Immediate attention should be paid to the prolific spread of certain weed species in the region and imminent action should be taken to eradicate them.

Agrochemicals

Loss of biodiversity means a loss of yield from ecosystems for humans (Tilman, 2000) and this has occurred to an extent in the Knuckles, where small holders and private land owners who still persist with cardamom will testify that productivity has decreased over the years. This decrease has resulted in people encroaching upon the forests around their lands in order to counter any loss of productivity. People have also resorted to using agrochemicals to increase productivity and we observed the wide application of agrochemicals including herbicides, insecticides and fertilizers in Kandyan home gardens, shifting cultivation and tea plantations adjoining the Knuckles conservation area. During the survey we observed the application of insecticides at several locations close to the conservation area border (Plate R15 Figure 5). This increasing application in agricultural lands will adversely impact the insect population, an important food source for most of the herpetofauna. Presently, some 100 active agents are applied to the environment for either agricultural or public health purposes. This is likely to be disruptive to local ecosystems and has the potential to adversely impact upon herpetofauna. Senanayake (1980) has also noted this and suggests that *C. tennentii* may be indirectly poisoned by Cardamom growers whose pesticide targets the lizard's prey. He goes on to outline a "strong correlation between the incidence of pesticide use and the demise of known populations of this lizard". Some tea workers in south western areas of the Knuckles commented that they have observed *C. tennentii* in certain areas of forest before the application of herbicide but that they did not see any further specimens after such an application. Farmers in Sri Lanka use 77-124kg of nitrogen fertilizer per hectare, which is 2 to 8 times more fertilizer than is used in any other country in the region (Baldwin, 1991).

Although there is no data regarding the direct toxic effects of pesticides on amphibians and reptiles, for humans it has become a leading cause of death in Sri Lanka (Ministry of Health 1999). Chemicals which are washed into streams by the region's heavy rainfall almost undoubtedly have severe adverse effects upon the amphibian species living within them, not to mention countless other species of fish, insects and reptiles. The relict amphibian *Adenomus kelaartii, Nannophrys marmorata and Lankanectes corrugatus* is a good example of a diminishing population possibly due to the draining of toxic chemicals into its habitat, observed in a Riverine Forest in Kandegama 750m above sea level (de Silva *et al.*, 2005o).

Development projects and increased predation risk

Recently there has been a significant increase in development in and around the Knuckles conservation area. Most of the new development projects have been related to tourism, which, while conducted across the world, can be dangerous if they do not benefit local populations whereby it can often lead to antagonism (Bhatt, 2002). Residents may not have access to the same resources, training, business experience and money as people from cities. This is certainly the case in the Knuckles, where the tourist industry is not benefiting the conservation forest or its dependent people. Although the Knuckles are well placed to promote eco-tourism and create incentives for local residents to actively participate in

the protection of the forests, so far such initiatives have not got underway in earnest. As a result the people do not see any benefits from conservation, and thus to subsidise their wages take part in small-scale tree felling, firewood collection, gem extraction and poaching, all of which are illegal.

There are many human habitations within the protected area as well as immediately below the conservation boundary and during our study more houses were constructed. The human population is high in the Knuckles region, with an estimated 60,000 people in 70 villages. Ninety cardamom barns have been recorded with an estimated 3000ha being actively cultivated for cardamom. Studies in other parts of the country have shown that there could be negative effects of this close proximity, including an increase in the predation of endemic herpetofauna species. As a result of habitat loss through agriculture and urbanization, many species have become more vulnerable to both domestic predators and native opportunistic fauna. During the survey we observed that many householders kept domestic cats and between 10 to 15 poultry. These are known predators of agamids, geckos, skinks and snakes (de Silva, 2001, de Silva *et al.*, 2004, Somaweera, 2001b) and thus pose an important new threat to the reptiles of the Knuckles. The poultry also feed on large quantities of various insects – which constitute the mainstay of many reptile diets.

At a survey undertaken amongst 27 adults and school students in the village of Meemure in the Knuckles, it was found that domestic cats were the main predator of geckos, with such predation having been witnessed by 96% of those surveyed. This was followed by snakes (48%) and ants (41%) (De Silva *et al.*, 2005u). Rats (*Rattus rattus*) and Wild boar (*Sus scrofa*) could also potentially predate upon herpetofauna and, particularly on reptile eggs before they are hatched. Fossorial reptiles are particularly threatened by aggressive ant species such as Kadiyas, which are common near human habitations. These have been observed killing *Rhinophis philippinus* in Kobonilagala (Plate R15 Figure 4).

The presence of rats often encourages residents to keep cats. It was observed in the village of Illukkumbura that households with cats had less *C. soba* and were instead populated with more common geckos. A civet cat was also observed inhabiting the loft of the project lodge in 2004, which could certainly be a potential predator of the gecko. Rats also attract rat snakes- *Ptyas mucosa* another potential predator of *C. soba*. Several raptors and snakes such as *Boiga*, *Oligodon*, *Elaphe* and *Lycodon*, (Plate R8 - R10) which are all found in the Knuckles, have all been observed to prey on geckos in other parts of the country (Somaweera, 2001b). In June 2005 an Oriental Magpie (*Copsychus saularis*) was observed predating on *C. soba*, seizing it from an outside wall of the lodge. Some specimens were observed having been killed by being caught between doors.

Other potential predators of herpetofauna which inhabited the forest adjacent to human habitations included the mongoose (*Herpestes fuscus, Herpestes edwardsi*), monkeys (*Macaca sinica*), crested serpent eagles (*Spilornis cheela*), common coucals (*Centropus sinensis*) and crows (*Corvus macrorhynchos*).

Furthermore, the considerable increase in distribution of the common agamid *Calotes versicolor versicolor* in forests may be an additional threat. According to Senanayake (1980) *Calotes versicolor* is a superior competitor and is gradually spreading to the upper montane regions. It is known to predate on juvenile Rhino-horned lizards, *Ceratophora stoddartii*, (Senanayake 1980) and on young *Sitana ponticeriana*. *Calotes nigrilabris* have also been observed to feed on young *Cophotis ceylanica* (de Silva, 2001). Although this *Calotes* species are not present in the Knuckles Mountains, it indicates nonetheless that agamids are certainly capable of eating one another.

Forest Fires

Forest fires have been identified as a considerable threat to ecosystems in the Knuckles. Hundreds of hectares of forests and grasslands are set on fire annually in the Knuckles (Plate 9 Figure 7). They are caused

accidentally through unsustainable honey collection techniques and traditional chena or slash and burn cultivation practices. On occasion, fires can burn out of control and consume swathes of natural forest and grassland. These fires may be a serious threat to the herpetofauna, including reptiles and amphibians that inhabit the forest floor and eggs that are laid in leaf litter. The threat of forest fire is an almost nightly feature of the lower slopes of the Knuckles range during the dry season, whereby farmers attempt to clear land for agriculture. Pine plantations, grasslands and scrublands are frequently set on fire, but while some trees such as the Pine are able to resist the fire, the creatures inhabiting the lower levels of vegetation are frequently killed. One *Cyrtodactylus soba* specimen (Plate 9 Figure 8) and one *Otocryptis nigristima* specimen (Plate R5 Figure 7) were observed burnt during investigations carried out immediately after fires.

Road kills

Over the last few years, increased road traffic in the region has resulted in a large number of road kill incidents, whereby reptiles, many of which are endangered, have been run over whilst crossing the road. This has been widely documented by the project. An appreciable number of dead agamids (Plate 2 Figures 1 & 8) were observed which included one *C. tennentii* (Plate 3 Figure 7) between Hunnasgiriya and Deanston and a few specimens of *C. liocephalus* between Loolwatte and Corbett's Gap (Plate 2 Figure 8). This stretch of road lies adjacent to suitable habitats for these species, and hence traffic poses a considerable threat to them, although at present, the volume of road traffic in the region remains low.

Due to the fragmentation of natural habitats several species such as *C. soba, Hemidactylus triedrus lankae* and *Geckoella triedrus* have been observed as being vulnerable to road kills (Bambaradeniya, et al., 2001). A good example was a *C. soba* observed crossing the road near Hunnasgiriya, which narrowly avoided death.

Numerous snake species were also found to be vulnerable to road traffic. All three specimens of *Macropisthodon plumbicolor palabariya* (Plate R15 Figure 6) recorded by the project were dead, having been run over by vehicles. A local resident reported seeing a *Python molurus* specimen on the Loolwatte to Meemure road having been run over by a vehicle. The specimen had later died from its injuries. Other species observed to have been killed by road traffic included *Ahaetulla nasuta, Xenochrophis asperrimus, Xenochrophis piscator and Coelognathus helena.*

Wanton Killings

Several forms of legal protection have been given to Sri Lankan herpetofauna. All geckos are listed as protected species in the country under the Flora and Fauna Protection Ordinance (Gunawardena, 1995). Nonetheless, wanton killings by people in their houses pose possibly one of the biggest threats to geckos in the Knuckles. In other parts of the country these killings are usually a result of unfounded beliefs that geckos are unclean, dangerous to children, poisonous and bearers of disease and even bad luck (Manamendra-Arachchi, 1997). Upon surveying local residents, it was apparent that most were scared of *C. soba* for the reasons cited above (see De Silva *et al,* 2005u). Being by far the largest species in the area *C. soba* is usually the gecko most vehemently removed from households. They are often killed, usually by being hit with a broom or other household implements, although there are occasional stories of some being doused in kerosene. Agamids have also been victims of certain rural beliefs such as the belief in many Sri Lankan communities that *L. scutatus* and other *Calotes* species are embodiments of spirits. In particular, the belief is that if a woman in labour dies she will later appear as a "bodilya" or agamid. Due to lack of knowledge and high snakebite morbidity and mortality in Sri Lanka, many Sri Lankans, including those living in the Knuckles are forced to assume that all snakes are venomous. Amongst the communities of the Knuckles, the standard procedure for dealing with a snake

encountered is to kill the snake. Almost every resident of the Knuckles carries a knife on his or her person and this is utilised in such an event. The result is the widespread killing of many snakes, venomous and non-venomous. Agricultural workers commit the majority of snake killings, usually when clearing overgrown vegetation for cultivation. This was especially evident with species such as *Daboia russelii, Hypnale, Bungarus* and mildly venomous snakes such as *Boiga* species, as well as non venomous snakes such as *Lycodon* and the Python.

Accidental mortalities of reptiles were noted throughout the Knuckles, which included incidents during land preparation (manually and with bulldozers), digging holes, ploughing and the clearing of foot paths and roads. It is reported that several fossorial reptiles have been accidentally killed during such activity, for example *Nessia sarasinorum* (Plate 7 Figure 8).

It is estimated that these unnecessary killings will only increase as human populations grow in the area.

Hunting

The hunting of reptiles was not seen as a major threat in the Knuckles. However, as in the rest of the country, some species such as *Varanus bengalensis, Crocodylus palustris, Melanochelys trijuga thermalis and Lissemys punctata punctata* were killed for their flesh.

Illegal collection

Although Sri Lanka is a signatory to the CITES (Convention on the International Trade of Endangered Species), no gekkotan lizard has been listed as protected from international trading. Although the Director of the Wildlife Conservation Department must permit legal export of any gecko or gecko part, there have been reports of illegal gecko collection in the Knuckles area, although it is not clear if this was for local or international collectors. Wickramasinghe and Somaweera (2005), also report that specimens of *Cnemaspis kandiana, Cyrtodactylus frenatus* and *Hemidactylus brookii parvimaculatus* were retrieved from lorries which were commercially transporting plants and vegetables. There is evidence that *Lyriocephalus scutatus* is traded both domestically and internationally due to demand in the pet trade, including eye-witness accounts from local residents that non-nationals have collected specimens for export.

Climate Change

Climatic changes over the past 100 years have been identified as a considerable threat to the ecosystems of the Knuckles. Studies on the annual rainfall of the Knuckles Range have shown a recent decrease (Giragama & Madduma Bandara, 1993). The annual rainfall at Kobonilla has decreased from 3800mm in 1982 to 3400mm in 1990 (Madduma Bandara 1991). This could have a detrimental impact on the reptiles, amphibians and other animals inhabiting the smaller more fragmented forest patches. Increasing temperatures and a decreasing annual rainfall has been recorded as a trend across Sri Lanka in the recent past (Fernando & Chandrapala, 1991). These changes in climate can have drastic impacts upon Sri Lankan herpetofauna. *Cophotis ceylanica* is a Montane cloud forest species, which may be sensitive to temperature increases over long periods. "A prolonged drought in the Nuwara-Eliya district in 1994 - 1995 resulted in the death of many individuals of the endemic and relict Pygmy Lizard" (Schaefer, 1998). A catastrophic mortality of *Cophotis ceylanica* was observed in the Hakgala area which coincided with a rise in the atmospheric temperature (de Silva, 1996; Palihawardana, 1998). Further changes in atmospheric temperatures may have severe implications for the specialised herpetofauna of the region.

The Diversity-stability hypothesis also suggests that the greater an ecosystem's biodiversity, the stronger its resilience, even to global climate change (Chapin, et al., 2000). However, as the entire Knuckles region is characterised, not only by biodiversity, but also by high climatic diversity, changes in any one of these climatic types could have serious effects for

the vegetation and in turn the animal species living alongside this vegetation.

CONSERVATION

Over the latter part of the twentieth century, the population of Sri Lanka experienced a rapid increase (Anon, 1993). The country currently has approximately 300 people per square kilometre, with the highest population density found in the Wet Zone (Pabla and Mathur, 2001). This is despite recent government initiatives that encourage population relocation in to the Dry Zone (Pabla and Mathur, 2001). With only 12% of the area of Sri Lanka's wet rainforest zone currently under forest cover (Green, 1993) Sri Lanka is also known to have the highest human population pressure among the biodiversity hotspots of the world (Cincotta et al., 2000). Urban and agricultural expansion has been cited as the primary cause of loss of forest cover. The Mahaweli Development Programme and increasing extent of chena or slash and burn cultivation has been blamed for a large proportion of recent losses. It is also important to note that the forest cover calculated is from aerial photographic surveys, which do not take into account the destructive under planting of exotic species such as those found in cardamom plantations or Kandyan forest gardens, and neither does it take into account the presence of invasive trees or monocultures such as Pine or Albizia, which may provide forest cover, but little assistance in terms of conserving biodiversity (Anon, 1993).

Most of the protected areas in Sri Lanka are situated in the Dry Zone. This is due to its historical background following the practise of British colonials during the nineteenth century, to use important ecosystems in the Dry Zone as hunting reserves. It was the demarcation of these reserves which developed into most of today's national parks, including Yala, which house many large and important animals such as elephant, leopard, crocodile and bear. However, if the global hotspot criteria of Myers et al (2000) are scaled down to national level to identify conservation 'priority' areas, it becomes clear that the majority of the country's endemism and deforestation occur in the Wet Zone. In other words, the Sri Lankan Wet Zone is more of a 'hot spot' than the Dry Zone and should therefore be receiving a much greater proportion of environmental conservation resources. Despite this, the Wet Zone to date has received relatively little attention.

Regardless of whether a species is present in a protected area or not there are numerous laws drafted for their protection. One of the most important is the 7th amendment to the Fauna and Flora Protection Act (No. 49 of 1993) which gave all of Sri Lanka's endemic species legal protection status, and active conservation measures were to be taken to safeguard them. The Department of Wildlife Conservation is empowered to enforce these provisions to protect such species. The Police and Sri Lankan Customs Departments are also empowered by the Fauna and Flora Protection Ordinance to enforce the provisions for species' protection.

KNUCKLES CONSERVATION

In 1969 under the auspices of UNESCO, the National Science Council (presently known as the National Science Foundation) formed a committee, selected several areas of natural beauty, planted them with forests and declared that they be protected under the "Man and Biosphere Progamme" (MAB). The Man and Biosphere Reserve concept stipulates that in addition to the importance of biodiversity within a reserve, local residents are also of prime concern. Dotulugala peak at an elevation of 1548m, the 4th highest peak of the Knuckles range, with an area of 1600ha was incorporated into this programme in 1975 (Sri Bharathie, 1979). Workshops were organised by the Forestry Department and the Ministry of Lands, Irrigation and Mahaweli Development with the assistance of the IUCN and with financial support from the Norwegian Agency for Development and Co-operation. Upon the recommendations made by an expert committee, a Cabinet decision was made in 1985 suggesting that the Knuckles range should be conserved further.

The first phase of reserve strategy was initiated between 1988 and 1991. Boundaries were defined, socio-economic surveys were conducted and promotional programmes were carried out at the national and international level aimed at attracting researchers from other countries. Awareness programmes were conducted amongst local residents to inform them of the important nature of the Knuckles forests. The management objectives of the strategy were primarily to protect the biodiversity, endemism and habitats of the region, then to promote the value of the forest amongst a national and global audience, and to encourage research and even eco-tourism. Of key concern was the improvement and maintenance of the forest hydrological systems, especially regarding its importance to the Mahaweli River. The fourth objective was to simultaneously improve the quality of life of the Knuckles residents. Conservation planning workshops included the discussion of issues concerning the local economy of the Knuckles, which was seen as an important factor in ensuring the protection of the area.

There were and still are implications in the banning of agriculture within the core zone of the Knuckles region. Cardamom is an important source of income for many residents and a ban would seriously affect livelihoods. Consultation with local residents was and still is thus necessary to allow for the management of the reserve to realistically apply its policies. A further planning workshop was held in 1993 to discuss both the progress of the reserve and proposals for future implementation of policy. It was decided that the boundary be redefined, so that all natural vegetation adjacent to the 1067 mark which isn't privately or community owned or actively being harvested for tea should also be protected. In addition, all adjacent abandoned tea land should be protected for use in the future for reforestation programmes. The entire area must be demarcated clearly so as to prevent confusion and minimise any issues of conflicting ownership or forest usage. All areas above 1067m were declared the core zone and all cultivation in this area was to be terminated with immediate effect due to its negative effect upon soil conditions and hydrology. It was assumed that the core forest would return unassisted to its natural state.

Land out with this new forest area but which lies adjacent to it down to 762m in altitude was to be declared the buffer zone. Here, the reserve would provide economic opportunities as alternative income supplements for residents who normally relied on environmentally unfriendly policies in the forest. Education was to be stimulated with school funding and the provision of scholarships. Non-forest orientated rural industries were also to be encouraged, such as farming - except on river banks or steep slopes - and the controlled harvesting of non-timber products such as kitul, rattan and medicinal plants. The buffer zone was also to be used as a location for agro-forestry research and replanting programmes. Experiments were to be conducted on the effectiveness of growing strains of cardamom at lower altitudes, perhaps even in pine plantations. Socio-economic surveys were to be conducted every three years in the region to assess the economic status and progress of local residents. It was decided that meteorological stations be established at the Forestry offices in Deanston and Illukkumbura. These offices were also to become the main centres for floral and faunal research studies.

On May 5th, 2000, an area of 17,500ha of the Knuckles range was declared the Knuckles Conservation Forest by Gazette Notification (Gazette No. 1130/22). Areas above 1,067m (3,500ft) in altitude and areas of adjacent forest are now protected.

The 'Hands off' approach of National parks and other protected areas, works in isolated areas in developed countries but in developing countries where many people rely on some of these protected areas for resources, simply declaring that they may no longer live or work there can have serious negative consequences, both social in terms of ruined economies, and also environmental as illegal extraction of resources of protected areas continues (Bhatt, 2002). The Man and

Biosphere proposal was developed to work towards solving this problem (Bhatt, 2002).

Conservation Management plans indicated the resettlement of the residents of the village of Kalupahana, who are mainly cardamom farmers, as this village lies within the core area. However, as of 1991, resettlement had not occurred, even though 98% of the village population desired to leave, especially if they were offered the opportunity of working on a tea estate, as many of them have previously been trained in the cultivation of tea (Kariyawasam, 1991).

The Knuckles Conservation area is currently being proposed as a World Heritage Site.

Recommendations

This study is a snapshot of the situation many amphibian and reptile species currently face in the Knuckles. The Knuckles study of 2004 and 2005 allowed us to formulate and propose the following recommendations, especially concerning the target species we investigated, *C. tennentii, Cophotis ceylanica, Calotes liocephalus, Cyrtodactylus soba* and *Chalcidoseps thwaitesii* as they currently face many threats in the area. However, further research is required on the following issues:

- It needs to be ascertained whether or not there is any evidence of a decline in the population of *Cophotis* in the Knuckles.
- If there has been a decline in number, it needs to be ascertained whether or not increases in temperature and a decrease in annual rainfall are responsible, thus indicating the sensitivity of *Cophotis* populations to Global Climate Change.
- The impact of alien invasive plant species in the Knuckles must be researched. The Convention on Biological Diversity calls for the control and monitoring of alien species, which threaten ecosystems, habitats, and species. Care must be taken to identify the extent of the threat, the current purpose or usage of the invasive species and the consequences of suddenly removing it from the environment, which it has invaded. In some instances, removing these species could even be more destructive than leaving them in place, as it may trigger further decrease in habitat quality. (Senanayake, 2001).
- The long-term effects of endemic species adapting to altered habitats needs to be investigated. There are a number of examples of adaptability of many endemic reptile species to human habitations and monoculture plantations in Sri Lanka and the Knuckles is no exception. We observed an abundance of the endemic forest geckos such as *Geckoella triedrus* and *Cyrtodactylus soba* inside dwellings in and around the Knuckles conservation area (refer de Silva et al., 2005a, de Silva et al., 2005b in this volume).
- The effects of human activity upon the prey species of agamids needs to be studied. *C. tennentii* is indirectly affected by the application of agrochemicals and pesticides which target its prey species, insects. Comparison needs to be made between specimens living in pristine and disturbed habitats.
- The status of the populations of *C. tennentii, Cophotis ceylanica, Calotes liocephalus, Cyrtodactylus soba* and *Chalcidoseps thwaitesii* needs to be ascertained. It is vital to establish exactly how many individuals remain alive today, and to determine the rate at which these numbers are decreasing. Monitoring is required to see if they are viable populations.
- The ability of the above species to migrate needs to be determined. It must be established whether or not they can traverse terrain without adequate forest cover or anthropogenic construction. Mark and recapture studies should be considered to see if a species can travel through such areas as this would allow it to re-colonise places which have lost their populations through fire or other unnatural events. If this is the case in some species, it will indicate whether or not that species will have viable sub populations in the range in the future.

- Obtaining the above data will be very useful for modelling and population viability analysis. This would enable conservationists to calculate the level of threat to populations of a particular species in the Knuckles. Obtaining the above data will help calculate the minimum or critical size of the habitat required to house a certain species according to its reproductive rate, emigration, habitat patterns and environment matrix quality as outlined by Fahrig (2001).
- Any captive breeding programmes should be used as an opportunity to examine the behavioural patterns of the species.
- Potential indicator groups or taxa should be investigated as a short cut to establishing areas that require higher protection on account of their biodiversity. This encourages more efficient park design (Howard, *et al.*, 1998) and ecosystem health.
- Successful protection is not likely to be achieved if the resource is looked at in isolation and without regard to the inter-relationships between people and forests (Panayotou and Ashton, 1992). There is thus an urgent need for social scientists and anthropologists to become more involved in conservation. They need to monitor the residents of places which require conservation (Faust *et al,* 2004).
- The restricted multiple usages of protected areas such as those in the buffer zone where agriculture requires monitoring to check that regulations are being followed. This requires resources and much money and is even subject to corruption, which again requires further monitoring and checking and thus more money and resources (*du Toit,* et al., *2003*).
- Guns are not allowed in the region due to civil conflicts in the country, thus alternative methods are employed to keep down wild pig populations such as traps, which are indiscriminate and can maim or kill elephants, leopards and even people (Pabla and Mathur, 2001). Proposals to allow and monitor the hunting of wild pigs on a community level, perhaps using trophy-hunting schemes should be considered. Revenue collected by the government could be redistributed in the form of compensation for any damages incurred to crops by pigs. This has been proposed in the Victoria Randinegala-Rantambe VRR sanctuary (Pabla and Mathur, 2001).
- Extraction of Non-Timber Forest Products (NTFP's) should be investigated and monitored to establish levels of sustainable and economically viable harvesting in the region.

Conservation measures to be taken:

- It has been suggested that a road sign campaign be launched whereby motorists are instructed to take care and try not to kill any reptiles or indeed any of the rare animals which are known to cross the roads of the region. The installation of road speed bumps should be considered as a precautionary possibility.
- As many private properties that lie within the conservation forest area are devoid of any tree cover it is proposed that a large reforestation programme be initiated with native trees from local seed sources.
- Habitat Matrix quality in the landscape should be improved as it is currently very heterogeneous, with disturbed and natural habitat types mixed together in close proximity. This can be altered, unlike other conservation factors such as species reproduction and emigration, which are beyond the control of science. The heterogeneity of a landscape has been found to be more important to the survival of a species than the fragmentation of the original habitat (Fahrig, 2001). This can be achieved by re-planting fragmented forest patches with native tree species to connect them with the main forest.
- Natural habitats should be enriched through the removal of all buildings within the protected area.
- Awareness programs should be conducted amongst hoteliers in the Knuckles to encourage them to exert the minimum amount of damage upon the

forest.

- Environmental Impact Assessments (EIA) should be conducted independently prior to any developmental activities proposed in the area.
- Ex-situ Conservation or Captive breeding programmes should be started for the future reintroduction of a species into its original habitat. Captive breeding should be initiated as an experimental project as insurance against any possible future declines or disasters in population numbers.
- It has become clear that simply maintaining the critical area is not enough to preserve it. The surrounding landscape must also be managed in a certain manner (Fahrig, 2001). It is important that authorities declare and manage a wider buffer zone around the Knuckles conservation area.
- Steps should also be taken to educate the local farmers in order to discourage the use of insecticides in the buffer zone, as this may be having a detrimental impact upon insect prey species.
- Current agricultural practices contribute to irreversible habitat degradation. However, traditional agricultural techniques developed in the region should be encouraged as these often allow for high natural biodiversity. They have been developed in conjunction with the biodiversity immediately present and are frequently more sensitive to it than certain more widespread farming techniques. Conservation farming encourages lower chemical inputs, uses crop residue for mulching, prevents rain erosion and soil crusting, reduces weeds and maintains soil fertility through an increased reinsertion of forest matter into the soil (Weerakoon, 1987). When used with certain legumes, mixed crop systems can significantly improve the levels of nitrogen in the soil, a more natural alternative to using fertilisers, thus reducing both chemical inputs and farmer's expenditures (Ranasinghe, 1991).
- Awareness programmes should be conducted amongst local residents on the benefits of conservation, offering advice on techniques such as sustainable resource consumption which can provide food, timber, medicines (Sayer, 1991) and the economic incentive of eco-tourism which would be encouraged by the balance and maintenance of local aesthetic and cultural values (Chapin *et al.*, 2000). Further benefits such as the prevention of erosion, and hydrological, nutrient and climate regulation and the subsequent economic incentives of such regulation should also be emphasised in these programmes (Balmford and Whitten, 2002).
- Local residents should be instructed in techniques of sustainable bee honey production, reducing the occurrence of destructive methods of honey harvesting currently pursued in the region which involve lighting fires and/or cutting down trees.
- The Knuckles are considered a climatic moderator due to their position and action upon meteorological systems. Furthermore, "one third of the water resources of the Victoria, Randenigala and Rantembe reservoirs originate from this range" (Ramakrishnan and Navaratne, 1991). Awareness programmes should be conducted amongst the national population outlining the above "Ecosystem services" whereby the natural environmental systems of the Knuckles contribute to the fertility, climate and hydrological regulation of Sri Lanka as a whole. This should encourage support for the protection of the Knuckles watershed forests which supply the Mahaweli Ganga, which is vital to the management of agricultural and residential practices of the country (Balmford and Whitten, 2002).
- Local residents needlessly kill many harmless reptiles in the belief that they are dangerous. Further awareness programs should be conducted so that people are able to identify species and recognise them as harmless, so as to discourage this killing. We issued stickers to a number of homes in the region informing the residents of the

useful nature of geckos (Plate 5 Figure 5 & 6) (Plate R15 Figure 7) showing that they play a major role in maintaining the ecological balance of the environment, especially in an agricultural country like Sri Lanka where they are preferable to pesticides for use as agents of biological control.

- Any captive breeding programmes should be extended to involve public awareness, and captive specimens should be available for the education of the public in certain designated places such as zoos or national park centres. Captive breeding should be seen as an opportunity to inform people of the importance and critical situation of the concerned species.
- Community based organisations - CBOs (such as a forest management committee, village women's organisation or village youth organisation) should be more encouraged, reformed and strengthened, with training provided in leadership skills, rural development, decision making and administration. This has been successfully implemented in the Sinharaja area around the Kanneliya-Dediyagala-Nakiyadeniya forest complex (Gunawardane, 2003). Local residents are the biggest and closest resource of manpower to these protected forests and have an intimate knowledge of the area. A sense of partial ownership of the forest should be encouraged and nurtured. Many of these people have been living amongst and harvesting resources from the forest for many generations and plantation workers even have to go into the forest to collect subsistence crops. These people have all come into contact with the areas biodiversity and will be most adept at identifying species, problems and ecological developments and would be the powerful guardians should they see their proximate environment as a resource which is best managed through protection as opposed to extraction (Bhatt, 2002).
- Kandyan Home Garden owners should be encouraged to invest more in the planting of firewood tree species so as to reduce pressure on forest for such resources (Pabla and Mathur, 2001).
- More stringent law enforcement should be implemented to prevent the illegal lighting of fires and encroachment into protected habitats.
- A permanent study plot should be established for the continued research of local reptile species.
- The conservation status of the Knuckles Range should be increased in order to protect its high biodiversity.
- Guides should be trained with additional language tuition in order to cater for foreign visitors, encouraging awareness and the growing eco-tourism market (Gunawardane, 2003).
- Although there have been large improvements in recent years on the part of the Forest Department (Plate R15 Figure 8), more informative material, trail guides, bird watching guides, maps, brochures, pamphlets and videos should also be provided to encourage awareness and promote eco-tourism (Gunawardane, 2003).
- Vigilance committees should be established with a limited number of community based organisation members selected to watch out for illegal activities. Where similar schemes have been instigated in the Sinharaja region, illegal logging was found to have been reduced by 75% (Gunawardane, 2003).
- Awareness programmes should be conducted on the spread of alien-invasive species. A good system of reporting of these alien-invasive
- species should also be established, preferably using local residents as the primary monitors where possible as they have a very good and widespread knowledge of the local regions and the plants of their forests.

Conclusion

The situation in Sri Lanka is similar to the dilemma faced by conservationists the world over. Many of its natural environments are under threat and there seemingly isn't enough money to prevent the loss of all of them. As was highlighted by Myers *et al.* (2000) the most threatened ecosystems are found in the tropics, in particular in developing countries such as

Sri Lanka. After the discoveries of Manamendra-Arachchi & Pethiyagoda (2005) it is clear that particular areas of the island are experiencing a higher rate of extinction than others. The current project has found that the Knuckles have a higher level of biodiversity than previously thought. It has also found that the region is under considerable threat from anthropogenic activities. After five decades of observation de Rosayro (1958) commented that the Knuckles had been relatively unaffected by anthropogenic influences. Today however, this picture could not be further from reality. The authors hope that by identifying the region as a high priority area requiring urgent attention, it will encourage the government and other institutions and organisations to allocate conservation funding and resources to protect this biodiversity hotspot, reducing the number of species extinctions. This would require innovative solutions, as well as commitment from all stakeholders if the Knuckles and Sri Lanka as a whole, are to significantly reduce biodiversity losses by 2010 in line with commitments made at the World Summit on Sustainable Development.

Plate R15 - Threats & Conservation

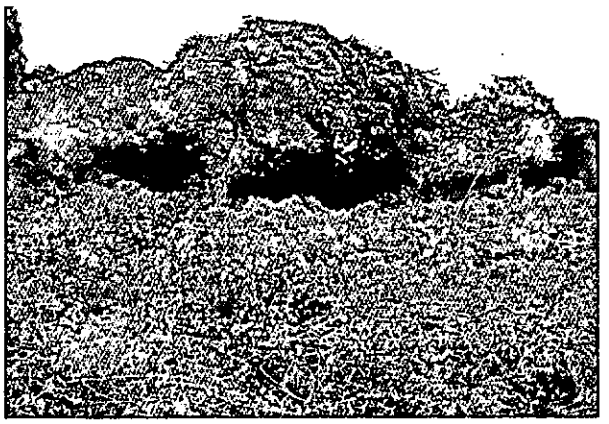


Figure 1 Deforestation ©JD

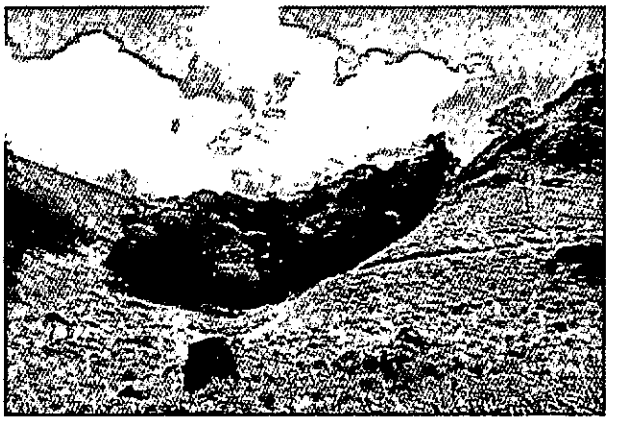


Figure 2 Habitat fragmentation ©SG

Figure 3 Invasive species ©JD

Figure 4 Uropeltid attacked by ants ©SG

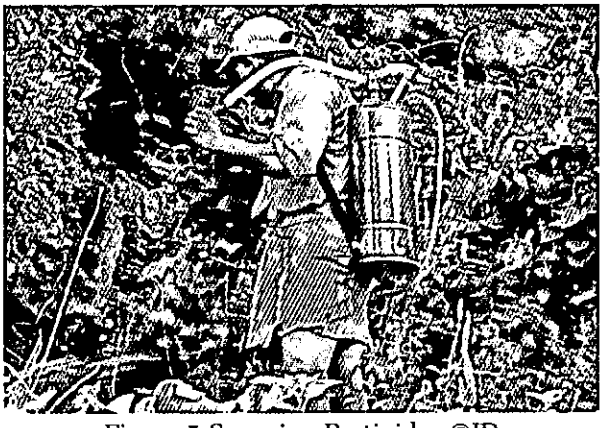


Figure 5 Spraying Pesticides ©JD

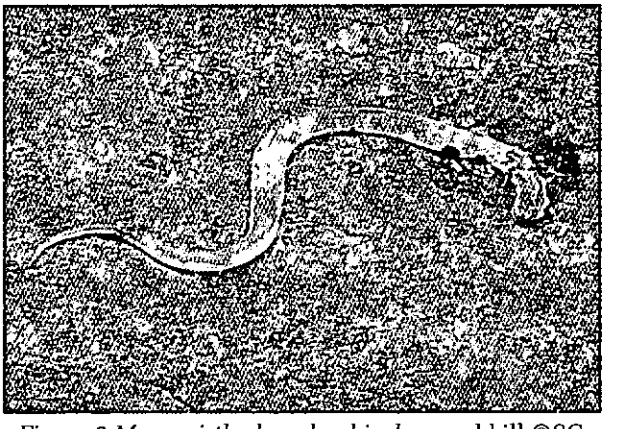


Figure 6 *Macropisthodon plumbicolor* road kill ©SG

Figure 7 Increasing awareness through stickers ©JD

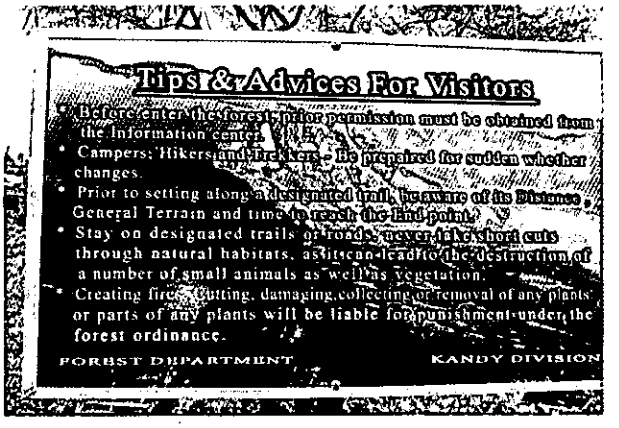


Figure 8 Advice to visitors by the Forest department ©SG

Literature cited

1. Abeygunawrdena, P. & J. R. Vincent, 1993. Bare Knuckles: fighting deforestation in Sri Lanka. *Harvard Institute for International Development*, Spring 1993: 1-17.

2. Abeywickrama, B.A., 1956. The origin and affinities of the flora of Ceylon, Proc. *11th Ann. Sessions of the C.A.A.S.* Part 2, 99-121.

3. Anonymous, 2003. *Statistical pocket book*, 2003. Department of Census and Statistics, Colombo.100p.

4. Austin, C. C., I. Das & A. de Silva. 2004. Higher-level molecular phylogenetic relationships of the endemic genus *Lankascincus* from Sri Lanka based on nuclear DNA sequences. *The herpetology of Sri Lanka: current research (including the Proceedings of the Fourth World Congress of Herpetology, Sri Lankan papers and the Nilgala Expedition papers). Lyriocephalus* Special Issue. Vol. 5 , Nos. 1 & 2: 11-22.

5. Avery, R. A., 1982. Field studies of body temperatures and thermoregulation. In: *Biology of the Reptilia* 12, Physiology C; Physiological Ecology p. 93 – 166. Gans, C. & Pough, F.H. Eds, London: Academic Press.

6. Bahir, M. M. & T. D. Surasinghe, 2005. A conservation assessment of the Sri Lankan Agamidae (Reptilia: Sauria). *The Raffles Bulletin of Zoology*, 12: 407-412.

7. Bahir, M. M. & A. Silva, 2005. *Otocryptis nigristigma*, a new species of agamid lizard from Sri Lanka. In: Yeo, D. C. J., P. K. L. Ng & R. Pethiyagoda (eds.), Contributions to biodiversity exploration and research in Sri Lanka. *The Raffles Bulletin of Zoology*, 12, 235-241.

8. Baldwin, M. F. (Ed.), 1991. *Natural Resources of Sri Lanka Conditions and Trends*. NARESA, Colombo, 280 pp.

9. Balmford, A. and T. Whitten, 2002, 'Who should pay for tropical conservation, and how should the costs be met?' in Oryx, volume 37, number 2.

10. Bambaradeniya, C. N. B., 2001. Threatened hepetofauna of Sri Lanka, In *An Overview of the Threatened hepetofauna of South Asia*, Bambaradeniya C. N. B. and Samarasekara V.N. (Eds). IUCN Sri Lanka pp118

11. Bambaradeniya C.N.B. and S.P. Ekanayake, 2003. *A Guide to the Biodiversity of the Knuckles Forest Region*. Colombo: IUCN Sri Lanka. 68 pp.

12. Bambaradeniya, C. N. B., J. M. Wickramasinge, V. A. P. Samarawickrama & L. D. C. B. Kekulandala, 2001. Herpetofaunal mortality in highways: a case study from Sri Lanka. *Abstracts Fourth World Congress of Herpetology*. Pp 10-11.

13. Bambaradeniya, C.N.B., P.K. Samarawickrema and K.B. Ranawana, 1997. *Some observations on the Natural History of Lyriocephalus scutatus (Linnaeus,* 1776) (Reptilia: Agamidae). *Lyriocephalus*, 3(1): 25-28.

14. Bandaratillake, H.M., 1988. Some hydrological aspects of the Knuckles region. Preliminary workshop for the preparation of a conservation plan for the Knuckles range of forests, Forest Department, Colombo, Sri Lanka.

15. Batuwita, S. & M. M. Bahir. 2005. Description of five new species of *Cyrtodactylus* (Reptilia: Gekkonidae) from Sri Lanka. In: Yeo, D. C. J., P. K.

L. Ng & R. Pethiyagoda (eds.), Contributions to biodiversity exploration and research in Sri Lanka. *The Raffles Bulletin of Zoology*, Supplement No. 12: 351–380.

16. Bhatt, S., 2003. Liking livelihoods with conservation – an enterprise-based approach to biosphere reserve management, in 'The South and Central Asian Man and Biosphere meeting of experts on environmental conservation, management and research', in the *'Journal of the National Science Foundation of Sri Lanka'*, Special Issue, Volume 31, Nos. 1 and 2.

17. Bickford, D. P., 1994. Diversity and abundance of a montane leaf-litter herpetofauna in Costa Rica: implications of elevational patterns. *Abstracts, Second World Congress of Herpetology*, University of Adelaide, Australia. p.11.

18. Bossuyt, F. & A. Dubois, 2001. A review of the frog genus *Philautus* Gistel, 1848 (Amphibia, Anura, Ranidae, Rhacophorinae). *Zeylanica*, 6(1): 1-112.

19. Bossuyt, F., M. Meegaskumbura, N. Beenaerts, D. Gower, R, Pethiyagoda, K. Roelants, A. Mannaert, M. Wilson, M. Bahir, K. Manmendra-Arachchi, P. K. L. Ng. C. Schneider, O. V. Oommen & M. C. Milinkovitch, 2004. Local endemism within the Western Ghats-Sri Lanka biodiversity hotspot. *Science.*, Volume 306. 479-481.

20. Chandraratne R. M. M., 1997. Some reptile bones from the Gedige excavation 1985, the citadel of Anuradhapura, Sri Lanka *Lyriocephalus* 3(2): 7-15.

21. Chapin, F.S. III, Zavaleta, E.S., Eviner, V.T., Naylor, R.L., Vitousek, P.M., Reynolds, H.L., Hooper, D.U., Lavorel, S., Sala, O.E., Hobbie, S.E., Mack, M.C. Diaz, S., 2000, 'Consequences of changing biodiversity' *Nature*, volume 405.

22. Cincotta, R. P., J. Wisnewski & R. Engelman, 2000. Human populations in the biodiversity hotspots. *Nature*, 404: 990-992.

23. Cohen, A. and J.T Carlton, 1998. 'Accelerated invasion rate in a highly invaded estuary' *Science*, volume 279, pp 555-558

24. Cooray, P. G., 1961. Geology of the country around Rangala. Geological Survey Department of Mineralogy, Government Press, Colombo 7-16.

25. Cooray, P. G., 1998. *The Knuckles massif – a portfolio.* Forest Department, Sri Lanka. 75 pp.

26. Cooray, P.G., 1984. *An introduction to the geology of Sri Lanka.* Department of Geology. Government printing press, Colombo, Sri Lanka.

27. Crump, M.L. and N.J. Scott, 1994. *Visual Encounter Surveys. In: Measuring and monitoring biological diversity: standard methods for amphibians.* pp. 84-92. Heyer W A et al (Eds.) Smithsonian Institute, USA.

28. Crusz, H. & D. M. A. K. Daundasekera, 1988. Parasites of the relict fauna of Ceylon. ix Helminths from burrowing scincine lizards.*Ann. Parasitol. Hum. Comp. Paris* 63(6): 439-447.

29. Crusz, H., 1984. Parasites of endemic and relict vertebrates: a biogeographical review, IN: *Ecology and Biogeography in Sri Lanka*, Ed. Fernando, C.H., Dr. W. Junk Publishers, The Hague; 321-51.

30. Crusz, H., 1986. The vertebrates of Sri Lanka: endemism and other aspects. *Rep. Soc. Res. Native Livestock* 11: 65-85.

31. Das, I. & A. de Silva, 2005. *A photographic guide to snakes and other reptiles of Sri Lanka.* New Holland, UK, 144 pp.

32. Davy, J., 1821. *An Account of the Interior of Ceylon and of its Inhabitants with Travels in that Island.* Longman, Hurst, Rees, Orme & Brown, London, 1st Ed. (2nd Ed. (1969) Tisara Prakasakayo, Dehiwala), 282.

33. de Silva, Anslem. 1980. The impact of Buddhism on the conservation of the Flora and Fauna in Ancient Sri Lanka. *Tiger paper* Vol 7 No 4 pp21-25.

34. de Silva, Anslem. 1990. *Colour guide to the snakes of Sri Lanka* R & A Publications ltd. Portishead, UK, 130 pp.

35. de Silva, Anslem. 1996. *The herpetofauna of Sri Lanka: a brief review.* Graphic Land, Kandy. 99 pp + 15 plates.

36. de Silva, Anslem. 1999. Survey of amphibians and reptiles of the canopy at the Horton Plains National Park, their associated parasites and conservation status. Zoological Survey of Sri Lanka. National Science Foundation. 67 p.

37. de Silva, Anslem. 2000. *The Conservation Assessment and Management Plan (CAMP) report.* The IUCN Conservation and Breeding Specialist Group (CBSG), Sri Lanka

38. de Silva, Anslem. 2001. Preliminary observations of the amphibian fauna at Horton Plains National Park. IN: *The Amphibia of Sri Lanka: current research.* Anslem de Silva et al (Eds.) pp. 64 – 88.

39. de Silva, Anslem. A., 2001. *The Herpetofauna of Sri Lanka: historical aspects and current status.* Ministry of Environment, 100 pp.

40. de Silva, Anslem. 2003. *The Biology and status of the star tortoise (Geochelone elegans) in Sri Lanka.* Ministry of Environment, 100 pp + 16 plates.

41. de Silva, Anslem, A. Bauer, C. Austin, S. Goonewardene, J. Drake, A. Balasubramaniam, C. Rajendran, V. Pathmadevan, M. Fernando & K.Sureshkumar. 2005j. Notes on *Nessia* species inhabiting the Knuckles massif with special reference to *Nessia bipes* (Smith, 1935) (Reptilia: Scincidae) : the dominant snake skink. *Lyriocephalus* Special issue, Volume 6 No 1 & 2: pp 115-123.

42. de Silva, Anslem, A. Bauer, S. Goonewardene & J. Drake. 2005d. *Ceratophora tennentii (*Gunther and Gray, in Tennent, 1861) (Reptilia: Agamidae), Some notes on its ecology. *Lyriocephalus* Special issue, Volume 6 Numbers 1 & 2: pp 55-62.

43. de Silva, Anslem, A. Bauer, S. Goonewardene, J. Drake & P. de Silva. 2005l. The Dumbara Bent-toed Gecko (*Cyrtodactylus soba*) the dominant gekkonid lizard inhabiting the Knuckles massif. *Lyriocephalus* Special issue, Volume 6 No 1 & 2: pp 137-144.

44. de Silva, Anslem, A. Bauer, S. Goonewardene, J. Drake, G. S. Samarawickrama & M. M. Goonasekera. 2005u. Some cultural traits and attitudes of the inhabitants of Mimure (in the Knuckles massif) towards local animals with special reference to herpetofauna. *Lyriocephalus* Special issue, Volume 6 No 1 & 2: pp 201-206.

45. de Silva, Anslem, A. M. Bauer, C. Austin, S. Goonewardene, J. Drake & P. de Silva. 2005i. *Chalcidoseps thwaitesii* (Gunther, 1872) (Reptilia: Scincidae) Four-Toed Skink: Preliminary observations. In The Diversity of the Dumbara Mountains

(The Knuckles Massif, Sri Lanka): With special reference to its herpetofauna. *Lyriocephalus* Special issue, Volume 6 No 1 & 2: pp 103-111.

46. de Silva, Anslem, A. M. Bauer, C. Austin, S. Goonewardene, J. Drake, P. de Silva, M.G.T.H. Aberathna, T. Dassanayaka, G. S. Samarawickrama, R.D.C.S.K. Dasanayaka, A.M.R.K. Amarakoon & M. M. Goonasekera 2005a. The Diversity of the Knuckles Ecosystem, with special reference to its Herpetofauna. *Lyriocephalus* Special issue, Volume 6 No 1 & 2: pp 13-33.

47. de Silva, Anslem, A., A. M. Bauer, C. C. Austin, S. Goonewardene, Z. Hawke, V.Vanneck, A.Drion, B.J.K. Perera, R.L.Jayaratne & M.M. Goonasekera,. 2004. Some cultural traits of the inhabitants of the Nilgala Fire Savannah, Sri Lanka, towards animals: with special reference to the herpetofauna IN: *The herpetology of Sri Lanka: current research, Lyriocephalus* Special Issue, Vol. 5, No 1&2. pp 183 - 191.

48. de Silva, Anslem, A. M. Bauer, S. Goonewardene, J. Drake, S. Nathanael, W.P.R.Chandraratne, and S.A.U.S. Somathilaka. 2005c. Status of the Agamids in the Knuckles massif with special reference to *Calotes liocephalus* (Gunther, 1872) and *Cophotis ceylanica* (Peters, 1861). *Lyriocephalus* Special issue, Volume 6 No 1 & 2: pp 43-52.

49. de Silva, Anslem, A. M. Bauer, S. Goonewardene, J. Drake, S. Nathaniel & P.de Silva. 2005k. Some observations on the geckos inhabiting the Knuckles massif. *Lyriocephalus* Special issue, Volume 6 No 1& 2:pp125-133.

50. de Silva, Anslem, K. B. Ranawana & S.Goonewardene. 2005q. Some observations on the molluscs of the Knuckles massif. *Lyriocephalus* Special issue, Volume 6 No 1 & 2: pp 179-182.

51. de Silva, Anslem, R. M. M. Chandraratne, S. Goonewardene, J.A.D.M.M. Jayasuriya, D. Ellepola, & P.B.N. Abeywardana. 2005r. Evidence of Prehistoric cave dwellers inhabiting the Knuckles massif: Preliminary archaeological findings. *Lyriocephalus* Special issue, Volume 6 No 1 & 2: pp 185-190.

52. de Silva, Anslem, R. M. M. Chandraratne, S. Goonewardene, J. Drake, J.A.D.M.M. Jayasuriya, H.M.N.W. Herath, P.B.N. Abeywardana & W. M. R. P. K. Chandradasa. 2005t. Some archaeological monuments and traditions of the North East Knuckles. *Lyriocephalus* Special issue, Volume 6 No 1 & 2: pp 197-200.

53. de Silva, Anslem, A., R. Meek, A. Bauer, S. Goonewardene, J. Drake, R.D.C.S.K. Dasanayaka, A.M.R.K. Amarakoon & M. M. Goonasekera. 2005e. First studies on thermal ecology of *Ceratophora tennentii* (Reptilia: Agamidae) inhabiting the Cloud forests of the Knuckles Massif, Sri Lanka. *Lyriocephalus* Special issue, Volume 6 No 1 & 2: pp 65-71.

54. de Silva, Anslem, R. P. V. J. Rajapaksa, R.R.M.K.K. Wijesundera, A. Bauer, S.Goonewardene, J. Drake, M. de Silva and N. A. N. D. Perera. 2005f. Preliminary investigation on the parasites of Agamids inhabiting the Knuckles mountain range, with special reference to *Ceratophora tennentii* (Reptilia: Agamidae). *Lyriocephalus* Special issue, Volume 6 No 1 & 2: pp 73-76.

55. de Silva, Anslem, R. P. V. J. Rajapaksa, R.R.M.K.K. Wijesundera, M. de Silva, A. Bauer, S.Goonewardene, J. Drake, C.C. Austin, N. A. N. D. Perera, D. de

Silva, U. Hemachandra , C. Nelawatura & D. A. Sathrasinghe. 2005p. Preliminary observations on some parasites of geckos, skinks and snakes inhabiting the Knuckles massif. *Lyriocephalus* Special issue, Volume 6 No 1 & 2: pp 173-177.

56. de Silva, Anslem, S. Goonewardene & R. M. M. Chandraratne. 2005s. A possible burial site with rock carvings from the Knuckles massif. *Lyriocephalus* Special issue, Volume 6 No 1 & 2: pp 193-194.

57. de Silva, Anslem, S. Goonewardene, J. Drake, & A. Bauer. 2005m. Observations of gecko cannibalism. *Lyriocephalus* Special issue, Volume 6 No 1 & 2: pp 147.

58. de Silva, Anslem, S. Goonewardene, J. Drake, & P. de Silva. 2005o. The amphibian diversity in the Knuckles massif with special reference to relict species. *Lyriocephalus* Special issue, Volume 6 No 1 & 2: pp 163-169.

59. de Silva, Anslem, S. Goonewardene, J. Drake, P. de Silva, R.D.C.S.K.Dasanayaka, A. M. R. K. Amarakoon & M. M. Goonasekera. 2005b. Species diversity and richness of the Herpetofauna in large leaf litter plots in the Knuckles Ecosystem. *Lyriocephalus* Special issue, Volume 6 No 1 & 2: pp 37-42.

60. de Silva, Anslem, S. Goonewardene, J. Drake, P. de Silva. 2006. Some observations on *Geckoella triedra* (Günther, 1864) inhabiting the knuckles massif, Sri Lanka. *Gekko.* Journal of the Global Gecko Association. (in preparation)

61. de Silva, Anslem. 2001. *The Herpetofauna of Sri Lanka: historical aspects and current status.* Ministry of Environment, 100 pp

62. de Silva, R.S.Y., 2001. C The impact of Buddhism on the conservation of the Flora and Fauna in Ancient Sri Lanka. *Tiger paper* Vol 7 No 4 pp21-25.

63. Deraniyagala, P. E. P., 1953c. *A colour atlas of some vertebrates from Ceylon. Vol.2 Tetrapod Reptiles.* Ceylon National Museum Publications. 101 pp.

64. Deraniyagala, P.E.P., 1931. 'Some Ceylon Lizards' in Pearson, J., (ed) *'Spoila Zeylanica' in the Ceylon Journal of Science, volume* 16 (2): 139-180, 1932, Colombo: Colombo Museum Publications.

65. Deraniyagala, S.U., 1992. *The Prehistory of Sri Lanka an ecological perspective,* Memoir Vol. 8, pt I and II, Department of Archaeology, Colombo.

66. Deraniyagala, P.E. P. 1953a. Limbless lizards of Ceylon. J. *Royal Asiatic Soc. (Ceylon Branch).* New Series. 3(1): 25-26 .

67. Deraniyagala, P.E. P. 1953b. Ceylon's Faunal Land Link with South Africa. *Ceylon Today.*1 (4):26.

68. Donnelly, M.A. and C. Guyer, 1994. Estimating population size. In: *Measuring and monitoring biological diversity: standard methods for amphibians.* pp. 97-102. Heyer, W. A. et al (Eds.) Smithsonian Institute, USA.

69. du Toit, J.T., B.H. Walker and B.M. Campbell, 2003. 'Conserving tropical nature: current challenges for ecologists' in Trends in Ecology and Evolution, volume 19, number 11.

70. Dutta, S. K. & K. Manamendra-Arachchi,1996. *The amphibian fauna of Sri Lanka.* Wildlife Heritage Trust of Sri Lanka. 230 pp.

71. Elton, C.S., 1958. 'Ecology of invasions of animals and plants', London: Chapman and Hall.

72. Erdelen, W., 1984. The genus Calotes (Sauria, Agamidae) in Sri Lanka: distribution patterns. *Journal of Biogeography*. 11: 515-525

73. Erdelen, W., 1988. Population dynamics and dispersal in three species of agamid lizards in Sri Lanka: *Calotes calotes, C versicolor and C. nigrilabris. Journal of Herpetology* 22(1): 42-52.

74. Fahrig, L., 2001. *How much habitat is enough?* Biological conservation. 100 pp65-74.

75. Faust, B.B., E.N. Anderson, J.G. Frazier, 2004. 'Rights, resources, culture and conservation in the land of the Maya', London: Praeger.

76. Fernando, T. K. & L. Chandrapala, 1991. Global warming and rainfall variability -Sri Lanka situation. *Proc. 47th Ann. Ses. Sri Lanka Assoc. Adv. of Sci.* Part., 1 : 138.

77. Fisher, A.C. and W.M. Hanermann, 1986. 'Option value and the extinction of species' *Advanced application of microeconomics,* volume 4, pp 169-190

78. Fitch, H. S., 1970. 'Reproductive cycles in lizards and snakes' *University of Kansas, Museum of Natural History,* Number 52, 1-247.

79. Foster, P.N., 2001. The potential negative impacts of global climate change on tropical montane cloud forests. *Earth-Science Reviews* 55: 73-106

80. Gans, C., 1995. New records of skinks from Sri Lanka. *Lyriocephalus* 2(1&2): 21-24.

81. Gazette, 2000. The Gazette of Democratic Socialist Republic of Sri Lanka (Extraordinary). No. 1130/22 of 5th may 2000. 30 pp.

82. Ginige, P., 1994. Reptile fauna of the Knuckles Range, Sri Lanka. *Lyriocephalus* 1(1&2): 38-43.

83. Giragama, W. M. G. B. & S.N. Wickramaratne, 2005. Climate and cloud study in the Knuckles Massif. *Lyriocephalus* Special issue, Volume 6 Numbers 1 & 2: pp 215- 231.

84. Goonewardene, S & A. De Silva, 2005. Observations on the Lyre Head Dragon: *Lyriocephalus scutatus* (Linnaeus,1758) (Reptilia: Agamidae) in the Central Province, Sri Lanka. *Lyriocephalus* Special issue, Volume 6 No 1 & 2: pp 313-323

85. Green, M. J. B., 1993. Conservation evaluation of some natural forests in Sri Lanka. In: Green, M. J. B & E. R. N. Gunawardena (compilers), Designing an optimum protected areas system for Sri Lanka's natural forests. IUCN – The World Conservation Union, Cambridge. 97 pp.

86. Greer, A. E., 1991. Lankascincus, a new genus of scincid lizard from Sri Lanka, with description of three new species. *Journal of Herpetology.* 25(1): 59-64.

87. Greer, A. E., Jr. & G. M. Shea. 2001. A major new head scale character in non-lygosomine scincid lizards. *Journal of Herpetology* 34: 629-634.

88. Greer, A. E., Jr. 1970. A subfamilial classification of scincid lizards. *Bulletin of the Museum of Comparative Zoology* 139(3):151-184.

89. Gunatilleke, C.V.S., I. A. U. N. Gunatilleke, A. U. K. Ethugala, N. S. Weerasekara, P. S. Ashton, P. M. S. Ashton & D. S. A. Wijesundara, 2004. Community ecology in an everwet forest in Sri Lanka. In: Losos, E. C. & E. G. Leigh, Jr. (eds.), Tropical forest diversity and dynamism: findings from a large-scale plot network, (eds). University

of Chicago Press, Chicago,. Pp.119–144.

90. Gunawardana, J., 1995. Legal protection of reptiles and amphibians in Sri Lanka. Lyriocephalus. Vol. 2 No. 1&2. pp. 88-91

91. Gunawardane, H. G., 2003. Ecological implications of cardamom cultivation in the high altitudes of Knuckles Forest Reserve, Central; province, *Sri Lanka. The Sri Lanka Forester.* 26: 1-9.

92. Gunawardane, H.G., 2003. 'Participation of buffer zone communities in the conservation and management of of southwest rainforests, Sri Lanka: some preliminary observations in The Sri Lanka Forester, volume 26, 2003, pp 63-65.

93. Henry, G.M., 1998. *A Guide to the Birds of Sri Lanka.* 3rd Edition. KVG De Silva & Sons, Kandy.

94. Howard, P.C., P. Viskanic, T.R.B. Davenport, F.W. Kigenyi, M. Baltzer, C.J. Dickinson, J.S. Lwanga, R.A. Matthews, and A. Balmford, 1998. 'Complementarity and the use of indicator groups for reserve selection in Uganda', *Nature,* volume 395.

95. Huey, R.B., 1982. Temperature, physiology and the ecology of reptiles. In: *Biology of the Reptilia* 12, Physiology C; Physiological Ecology 25 – 91. Gans, C & Pough, F.H. (Eds). Academic Press, London.

96. Huey, R.B., E.R. Pianka, M.E. Egan and L.W. Coons, 1974. Ecological shifts in sympatry: Kalahari fossorial lizards (*Typhlosaurus*). *Ecology* 55: 304-316.

97. IUCN Sri Lanka & Forest Department, 1994. *Management plan for the conservation of the Knuckles Forest. Phase 2.* Forest Department, Colombo. 58 pp + appendices.

98. IUCN, 2000. *The 1999 list of threatened fauna and flora of Sri Lanka.* Colombo: IUCN Sri Lanka. 114 pp.

99. IUCN, 2004. Conservation International, and NatureServe. Global Amphibian Assessment. <www.globalamphibians.org>. Accessed on 15 January 2006.

100. Jaeger, R.G. & R.F. Inger, 1994. *Quadrat sampling. In: Measuring and monitoring biological diversity: standard methods for amphibians.* pp. 97-102. Heyer W A et al (Eds.) Smithsonian Institute, USA.

101. Jones, C.G., R.S. Ostfeld, M.P. Richard, E.M. Schauber, J.O. Wolff, 1998. 'Chain reactions linking acorns to gypsy moth outbreaks and Lyme disease risk' *Science,* volume 279, pp 1023 – 1026

102. Kariyawasam, D., 1991. "Resource use and settlement in the forests of the Knuckles Range' *The Sri Lankan Forester,* volume 20, numbers 1 and 2, 1991, pp 3-13

103. Kluge, A.G., 2001. Gekkotan Lizard Taxonomy. *Hamadryad.* Madras Crocodile Bank Trust, India. 26(1): 1-209.

104. Koelmeyer, K.O., 1957. Climatic classification and the distribution of vegetation in Ceylon. *The Ceylon Forester* July- December 1957 Vol. III No. 2 (New Series), 144-163.

105. Lawrie, A. C., 1898. *A gazetteer of the Central Province of Ceylon.* Volume 2. Government Printer, Colombo. Page 594.

106. Lodge, D., 1993. 'Biological invasions: lessons for ecology' in *Trends in Ecological Evolution,* volume 8, pp 133-137

107. Maduma Bandara, C. M., 1991. Climate and hydrology of the Dumbara Hills. *Annual Review 1990.* Institute of Fundamental Studies, Kandy. p. 51.

108. Manamendra-Arachchi, K. & R. Pethiyagoda, 2005. The Sri Lankan shrub-frog of the genus *Philauts* Gistel, 1848 (Ranidae: Rhacophorinae), with description of 27 new species. *The Raffles Bulletin of Zoology*. Supplement 12.: 163-303.

109. Manamendra-Arachchi, K., 1997. Gecko! *Sri Lanka Nature* 1 (1): 45-55.

110. Manamendra-Arachchi, K. N. and S. Liyanage, 1994, 'Conservation and distribution of the agamid lizards of Sri Lanka, with illustrations of the extent of the species' in the *Journal of South Asian Natural History,* April 1994, Volume 1, number 1, pp 77-96.

111. Manamendra-Arachchi, K., 1990, ' A guide to the agamids in Sri Lanka', in Young Zoologist's Association, Occasional Papers, number 5, July, 1990.

112. Marambe, B., L. Amarasinghe & G. Gamage Pallewatta, 2003. Sri Lanka, In Invasive Alien Species in South- Southeast Asia: National Reports & Directory of Resources. Pp 91- 103. N., J.K. Reaser, and A.T. Gutierrez (eds.). Global Invasive Species Programme, Cape Town, South Africa.

113. Margules, C.R.and R.L., Pressey, 2000. 'Systematic conservation planning', *Nature,* volume 405, May 2000, pp 243 – 253.

114. McCann, K.S., 2000. 'The diversity-stability debate' *Nature,* volume 405, May 2000

115. Meegaskumbura, M. & K. Manamendra-Arachchi, 2005. Description of eight new species of shrub-frogs (Ranidae: Rhacophorinae: *Philautus*) from Sri Lanka. *The Raffles Bulletin of Zoology*. Supplement 12.: 305- 338.

116. Meegaskumbura, M., F. Bossuyt, R. Pethiyagoda, K.Manamendra-Arachchi,M. Bahir, M. Milinkovitch & J.C.Scneider, 2002. Sri Lanka:an amphibian hotspot. *Science,* 298:379.

117. Meffe, G.K. and C.R. Carroll, 1997. *Habitat Fragmentation. In: Principles of Conservation Biology.* Pp 269-304. Sinauer Associates Inc. Massachusetts.

118. Miller, M., 2006. Geckobia Mites. Global Gecko Association. *Chit-Chat* No. 17

119. Mitchell, A.W., K.R.J. Secoy and T. Jackson (eds), 2002. The Global Canopy Handbook: Techniques of Access and Study in the Forest Roof. The Global Canopy Programme, Oxford.

120. Moorman, F.R. and C.R. Panabokke, 1961. Soils of Ceylon. *Tropical Agriculturist,* Vol. CX VII, 5-65.

121. Myers, N., R.A. Mittermeier, C.G. Mittermeier, G.A.B. Fonseca, and J. Kent, 2000. *Biodiversity hotspots for conservation priorities.* Nature 403: 853-858.

122. Naggs, F. & D. Raheem, 2000. *Land snail diversity in Sri Lanka.* The Natural History Museum, London. xiii + 243.

123. Naggs, F. & D. Raheem, 2003. The Darwin Initiative project on Sri Lankan land snails: patterns of diversity in Sri Lankan forests. *Molluscan Conservation and Biodiversity,* Special Publication Conchological Society, 8pp.

124. Navaratne, W. M. & C.M. Madduma Bandara, 1993. Cardamom

cultivation in the Dumbara Hills (Knuckles Range) and its environmental impact. *Annual Review* 1992. Institute of Fundamental Studies, Kandy. pp. 73-74.

125. Navaratne, W. M. & C.M. Madduma Bandara,1995. Categorization and analysis of plant and soil in two types of forest in the Dumbara Hills (Knuckles Range). *Annual Review* 1994. Institute of Fundamental Studies, Kandy. pp. 81-81.

126. Pabla, H. S. and V. B. Mathur, 2001. 'Planning for Conservation of Biological Diversity: Lessons Learnt from Sri Lanka', *Loris, Journal of the Wildlife and Nature Protection Society of Sri Lanka,* Volume 22, Number 5

127. Palihawadana, A., 1998. An Ecological study of the *Cophotis ceylanica pp253-260.In Biology and Conservation of the Amphibian, Reptiles and their Habitats in South Asia.* de Silva, A.(Ed) Amphibian and Reptile Research Organisation of Sri Lanka.

128. Panayotou, T. and P.S. Ashton, 1992. 'Not by timber alone: economics and ecology for sustaining tropical forests', Covelo: Island Press.

129. Pethiyagoda, R. and K. Manamendra-Arachchi, 1998. *A revision of the endemic Sri Lankan agamid lizard genus Ceratophora Gray, 1835, with description of two new species,* in the *Journal of South Asian Natural History,* Volume 3:1 January 1998.

130. Pethiyagoda, R. & K. Manamendra-Arachchi, 1998. Evaluating Sri Lanka's amphibian diversity. *Occasional Papers No. of the Wildlife Heritage Trust.* pp 1-12.

131. Premadasa, M.A., 1984. Grassland. In:Fenando, C.H.(ed.), *Ecology & Biogeography in Sri Lanka,* Dr.W. Junk publishers, The Hague. 99-131.

132. Purvis, A. and A. Hector, 2000. 'Getting the biodiversity' *Nature,* volume 405, May 2000.

133. Ramakrishnan, A. and W.M. Navaratne, 1992. The environmental impact of land use in Knuckles Range. Department of Geography, University of Peradeniya, Sri Lanka (unpublished paper).

134. Ranasinghe, D. M. S. H. K., 1991. *Agroforestry and community forestry in Sri Lanka.The Sri Lanka Forester,* 20 (1 & 2) 45-49.

135. Ranawana, K.B., 2005. Land mollusks in the Knuckles Region, Sri Lanka. (Unpublished report)

136. Rathnayake, N. D, A. N. Weerasinghe, K. Amarasinghe, C. Gamlath, D. Rathnayake, C. Irrugalrathne & H. Wijesinghe, 1999. *An ecological study on flora and fauna of Knuckles range – Sri Lanka (Northern region).* Youth Exploration Society of Sri Lanka, Peradeniya, 33 pages (mimeographed).

137. Rathnayake, N. D., 2001. Notes on some amphibians observed in Knuckles Range. *Lyriocephalus,* 4 (1 & 2): 121-123.

138. Rathnayake, N.D., 2001. 'Some notes on Sri Lankan Cat Snakes', *Loris, Journal of the Wildlife and Nature Protection Society of Sri Lanka,* June 2001, Volume 22, Number 5.

139. Ratnayake, H. D., 2005. Some aspects of the vegetation of the Knuckles ecosystem. *The Diversity of the Dumbara Mountains (The Knuckles Massif, Sri Lanka): with special reference to its herpetofauna. Lyriocephalus* Special issue, Volume 6 Numbers 1 & 2 pp 233-266.

140. Rodrigo, R.K. & D. Jayantha, 2004. An observation of the foraging behaviour of *Ceratophora tennentii* Günther, 1861, Knuckles Forest Range in Sri Lanka. *Reptile Rap*, Newsletter of the South Asian Reptile Network, No. 6: pp 11.

141. Röhling, E.J., M. Fenton, F.J.Jorissen, P. Bertrand, G.Ganssen & J.P. Caulet, 1998. Magnitudes of sea-level lowstands of the past 500,000 years. *Nature*, **394**:162-165.

142. Rosayro, R. A. de., 1958. The climate and vegetation of the Knuckles region of Ceylon. *The Ceylon Forester*, 3(3 & 4): 201-260.

143. Samarakoon, S. M. M., 2004. *Dasia halianus* (Reptilia: Scincidae) a new locality record. *The herpetology of Sri Lanka: current research (Including the Proceedings of the Fourth World Congress of Herpetology, Sri Lankan papers and the Nilgala Expedition papers)*. *Lyriocephalus* Special Issue. 2004, Vol. 5 , Nos. 1 &2:

144. Samarawickrama, H.M.G.S., 2005. An Ethno-archaeological study of the inhabitants of Mimure, Knuckles. *Lyriocephalus* Special issue, 2005 November, Volume 6 Numbers 1 & 2: pp 285- 290.

145. Sarasin, P. and F. Sarasin, 1908. *Ergebnisse Naturwissens chaftlicher Forschumgen auf Ceylon. 4 die steinzeit auf Ceylon. Wiebanden,* C.W. Kreidel (In S.U. Deraniyagala 1992 The Prehistory of Sri Lanka an ecological perspective).

146. Sayer, J., 1991. 'Rainforest buffer zones: guidelines for protected area managers', Gland: IUCN Switzerland

147. Schaefer, D., 1998. 'Climate change in Sri Lanka? Statistical analyses of long-term temperature and rainfall records', in Domroes, M. and Roth, H., 'Sri Lanka: past and present - archaeology, geography, economics - selected papers on German research', pp 103-107, Weikersheim: Margraf Verlag

148. Seligmann, C. G. & B. Z. Seligmann, 1911. *The Veddas*. Cambridge University Press. Pp. 318-321.

149. Senanayake, F.R., 1980. The status of endemic lizards, genus: *Ceratophora*. Sri Lanka. *Tiger paper* 7(4): 26-28.

150. Skeen, W., 1868. *The Knuckles and other poems*. W. L. H. Skeen & Co, 41 Chatham Street, Colombo. 181 pp.

151. Smith, M. A., 1935. *The fauna of British India, including Ceylon and Burma. Reptilia & Amphibia. Vol. 11-Sauria*. Taylor & Francis, London. 440 pp.

152. Smith, M. A., 1943. *The Fauna of British India, Ceylon and Burma, including the Whole of the Indo-Chinese Sub-Region. Reptilia and Amphibia Vol. 3 - Serpents* (R.B.S. Sewell editor) Taylor and Francis, London, xii + 568 pp.

153. Somaweera R.K., K.D.B. Ukuwela & S.B. Karunaratne, 2001b. Menikdena: a Local Herpetofauna Hotspot. *Occasional Papers of the Amphibia & Reptile Research Organization of Sri Lanka* . pp 8

154. Sri Barathi K. P., 1979. Man and Biosphere reserves in Sri Lanka. *Sri Lanka Forester.* 14 (1 & 2): 37-40.

155. Sri Barathie, K.P., 1988. 'Present status of the management and protection of the Knuckles Range of forests', Paper presented at a workshop on the preparation of a Conservation Plan for the Knuckles Range of forests, Colombo: Sri Lankan Department of Forestry.

156. Stuart, S., J. S. Chanson, N.A. Cox, B.E. Young, A.S.L. Rodrigues,

D.L. Fischman & R.W. Waller, 2004. Status and trends of amphibian declines and extinctions worldwide. *Science,* 306: 1783-1786.

157. Taylor, E. H., 1953. A review of the lizards of Ceylon. *Uni. Kansas Sci. Bull.* 35(12): 1525-1585.

158. Tilman, D., 2000. 'Causes, consequences and ethics of biodiversity' Nature, volume 405.

159. Tryon, B. W., 1977. 'Notes on the reproduction of the lizard Cophotis ceylanica', *British Journal of Herpetology,* Volume 5, pp 845 – 847.

160. Uragoda, C. G., 1973. Nitre cave and its environs. *Journal of the Royal Asiatic Society (Sri Lanka).* 17: 37-35.

161. USOT Assesment, 1993. ' Harmful Non=Indigenous Species in the United States', Washington: United States Government Printing.

162. Weerakoon, D. K., 2002. '*Canopy Arthropod studies in Sri Lanka: Implications for Conservation*', in '*The South and Central Asian Man and Biosphere meeting of experts on environmental conservation, management and research*', in the '*Journal of the National Science Foundation of Sri Lanka*', Special Issue, Volume 31, Nos. 1 and 2, March and June 2003.

163. Weerakoon, E.L., 1987. 'Aspects of conservation farming', A paper produced by the Maha Illuppallama Agricultural Research Station

164. Werner, W., 1988. Canopy dieback in the upper montane rainforests of Sri Lanka. *Geographical Journal* 17: 245-248.

165. Werner, W., 1982. The upper montane forest of Sri Lanka. *The Sri Lanka Forester,* Vol. 15, 119-35.

166. Werner, W., 2001. *Sri Lanka's magnificent cloud forests.* WHT Publications, Colombo.96pp

167. Wickramasinghe, L.J.M & R. Somaweera, 2005. Distribution and Current Status of the Endemic Geckos of Sri Lanka. *Gekko* The Journal of the Global Gecko Association. Volume Three, Issue One pp1-13.

168. Wijesinghe, L.C.A.D.S., 2000. *Biological Diversity.* In: Natural resources of Sri Lanka. Pp251-266. National Science Foundation. Colombo.

Plate R16 - The research teams

Figure 1 Edinburgh and Rajarata university students (2004) ©SG

Figure 2 Edinburgh and Jayawardenepura university students (2004) © SG

Figure 3 Rajarata university students (2005) ©AdS

Figure 4 Peradeniya university Archeology students (2005) ©AdS

Figure 5 Jaffna university students (2005) ©AdS

Figure 6 Eastern university students (2005) ©JD

Figure 7 Jaywardenepura university students (2005) ©AdS

Figure 8 Edinburgh and Peradeniya university students (2005) ©SG

Plate R17 - Poster

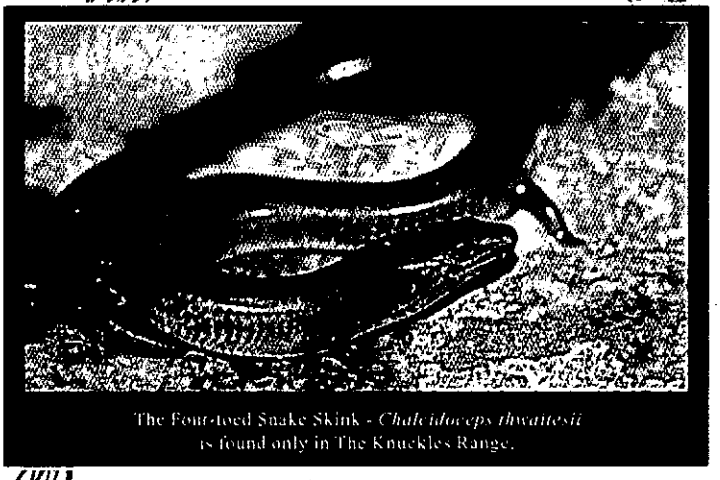
SOME OF THE RAREST SPECIES OF REPTILES IN THE WORLD FOUND ONLY IN THE KNUCKLES RANGE

The Knuckles Mountain Range
Sri Lanka

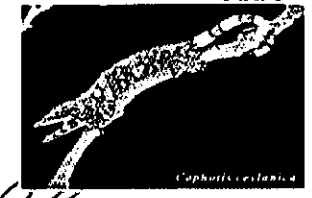
The Leaf Nosed Lizard - *Ceratophora tennentii*
is found only in The Knuckles Range.

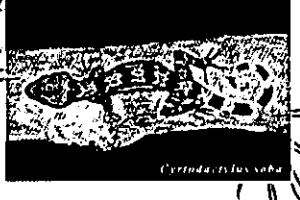
HELP SAVE OUR FORESTS !

Or we'll soon be EXTINCT !



The Four-toed Snake Skink - *Chalcidoseps thwaitesii*
is found only in The Knuckles Range.





HESSAGE BY : AMPHIBIA & REPTILE RESEARCH ORGANISATION OF SRI LANKA & PROJECT KNUCKLES (UNIVERSITY OF EDINBURGH) - Nov 2005
www.hoora.co.uk

Annexure 1
Canopy sampling in the Knuckles

Introduction

Forest canopies are difficult and hazardous environments in which to work. As a result, forest canopies are amongst the least explored regions of the world, second only to the deep oceans. These habitats are rich in both floral and faunal diversity. Sadly, activities such as logging, hunting and farming severely threaten forest canopies and their resident species. As a result, it is very important that these species are studied immediately, in an attempt to safeguard their future. However, the forest canopy inhabitants are elusive and infinitely more adapted to their environment than the beleaguered humans who attempt to study them. Data is thus scarce and plans for future research continue to face the same difficulties as those faced by expeditions in the past – dense foliage, dangerous animals, environmental parameters and the omnipresent constraint of gravity.

Knowledge of the forest canopies of Sri Lanka is limited due to the inability to safely access them and thus, the unique forests of the Knuckles Mountains have never been studied. The potential of any canopy research on the island had been demonstrated by a number of previous studies, for example de Silva (2001) conducted the first systematic canopy sampling for amphibians and reptiles at Horton Plains in 2000, where *Ramanella palmata*, (Amphibia: Microhylidae) which was previously considered to be rare by herpetologists, was found to be common in tree holes over 5 to 6m above the ground. WHT studies between 1994-2003, where simple observations made on the lower canopy in numerous locations in the county have also led to a number of new species of amphibian being found, of which some have been recently described (Manamendra-Arachchi & Pethiyagoda. 2005; Meegaskumbura & Manamendra-Arachchi

2005.) and more currently awaiting formal classification (pers. com. Manamendra-Arachchi). The lack of research of the forest canopies in Sri Lanka means that figures of discoveries look set to continue with further research in these elusive areas (pers. com. Manamendra-Arachchi), as well as valuable ecological information on Endangered species such as *P. caviostris*, whose males have never been observed and thought to only Inhabit the forest canopy (Manamendra-Arachchi & Pethiyagoda, 2005). Project Knuckles was the next expedition set to study the forest canopy in the country. It was hoped that if the canopy sampling of Project Knuckles was successful it could lead to very interesting findings and make a substantial contribution to the understanding of this unique habitat and its arboreal herpetofauna. There is also the potential of discovering new species.

During the 2004 phase of the expedition, it was found that the rope based canopy sampling method (See Notes below for details) wasn't versatile enough to sample canopy-dwelling reptiles effectively, due to the high difficulty to catch specimens. Of the trained team and traditional tree climber, it was the latter who was able to catch specimens for examination. The former were able only to make observations on the activities of the various reptiles and amphibians living around the main stem of the studied trees. While this was of little use in terms of sampling the population numbers of reptiles and amphibians living in the canopy, Project Knuckles realised that canopy rope studies could at least be used to study the behavioural patterns of arboreal reptiles and amphibians. The traditional tree climber, remains to be a crude tool that can be used to estimate species richness and abundance but difficult to adapt and make a standardised herpetological research technique.

Results

Eight trees were sampled over 5 days. Four *Cnemaspis* specimens, an abandoned

mammal's nest (probably a rodent) and two molluscs were found under bark.

Discussion

Accessing the canopy using the two-rope technique is time consuming but is worth pursuing, after noting its limitations, which makes it a tool better suited for behavioural studies than pure canopy exploration. The climbing ropes should be set up as early in the day as possible and in hoping that an individual is identified a tree boat (a portable tree tent) should be set up from where the behaviour of the individual can be watched without disturbing it. The leading lines can be left in the tree over night (in safe areas) so that the climbing ropes can be inserted quickly the following day. If multiple trees are to be sampled at once a large team of people should be trained as there should be two people working on a tree at all times. Climbing equipment would also be needed for each tree. This will be a limiting factor depending upon the available budget.

Local climbers are useful as they can insert lines quickly and search a number of trees that are inaccessible to the harnessed climber. The climber can cover a larger area of the tree over a short period of time, and so is much more efficient than the harnessed climber at assessing the situation and making initial observations. Unfortunately local climbers can only access certain trees and to a limited height. Furthermore, this technique has numerous risks associated with it, as the climber is not secured to the tree in any way. Harnessed climbers are therefore better used for accessing trees that are inaccessible to local climbers. They can also work for longer periods of time where a tree boat can be assembled.

Future research could include the identification of prospective sites to perform a study. When trees are identified to have species that can be observed, behavioural studies could be undertaken. These could include studies on competition, feeding, predation and life cycle.

The little literature available suggests that visual encounter survey method is not suitable for arboreal herpetofauna research (Crump and Scott, 1994). Different survey models as well as trapping methods should be experimented with to address void. Suggestions include the use of artificial habitats, a modified pitfall trap, and camera traps that are triggered by a moving individual on passing. Traps could be left for several nights, but should be checked regularly during a day and there should be several traps per tree where possible. A sticky trap was tested during 2004. This consists of a crepe bandage with rat glue on it being wrapped around a tree trunk or branch. Any specimens that are caught can be removed using vegetable oil that dissolves the glue. When an individual is caught the direction of its travel can be seen, giving behavioural information. This technique was carried out once but was found to be complicated with dehydration, shock and predation posing potentially cruel problems to the captured lizard or gecko. A *Cnemaspis* species specimen was captured and successfully freed, unharmed from a Jak Fruit tree. The glue trap was placed 1 metre above ground level around the trunk. The *Cnemaspis* was found to be moving up the tree at some time between early evening and late morning the following day.

In order to study the insects on which many canopy reptiles feed lumonic light traps could be used to capture insects, mainly Lepidopteran. The light traps are raised using single rope techniques and between a tree pulley system. Suspended soil sampling can be used to sample the soil created by epiphytes. A large number of arthropods inhabit such places. Ultra violet dust can be used for night work. Collected individuals can be sampled, powdered and at night, observed in the canopy using UV light.

Conclusion

As Project Knuckles focused primarily on ground level research only a week was allocated for canopy research. This was found to be too short a time period for any substantial findings to be made. Canopy

research over a longer period of time could lead to a large contribution of new information about the herpetofauna and the unique habitats of the Knuckles Range. Crucially, however, this study will be the first herpetological study of the canopy in the world using these techniques. This proves both a challenge and an opportunity for the team, whilst the prospects of such a study are exciting; there are no previous examples from which to draw experience. Canopy research is a relatively new discipline, and canopy research directed at herpetofauna has barely been conducted in the past. There is subsequently a considerable lack of literature covering the techniques and the application of this methodology for the study of reptiles and amphibians inhabiting forest canopies. This was a major constraint to the project. Large amounts of time and effort had to be spent on formulating, trying and testing different solutions to address the issues faced.

However, with time and the investment of effort and resources, canopy research methodology can only improve and it is hoped that with this improvement will come new discoveries in the forest canopies, in Sri Lanka and around the world.

Notes on Canopy access in the Knuckles.

There are very few tried and tested methods for sampling a forest canopy. Past techniques have involved monkeys, canons and intricate rope systems (Mitchell *et al*, 2002). The latter would appear the most versatile and is thus the most viable for future investigations. However, the prospect of sending a human into the forest canopy on a rope is still problematic. The single rope techniques traditionally employed by canopy researchers are no longer compliant with European Health and Safety Law. Climbers are still exposed to all of the above dangers, and while being suspended from a rope can offer an escape route from certain dangers, it can also act as the primary cause of others. Ropes are not indestructible and many can be damaged by climatic factors, animal action and any number of constituent factors of the term 'wear-and-tear'. First and foremost is the safety of each individual involved in any such canopy operation so this legal failing has had to be addressed. Rope techniques have thus evolved to cater for eventualities such as the failure of one rope or any number of biological or climatic incidents, which provide the climber with an urgent need to return to the ground. The developed techniques have been tested and approved by various relevant institutions. It is now possible to gain proficiency in rope access techniques to a level, which is in accordance with European Health and Safety Guidelines. This has opened up new avenues for forest canopy research around the world.

In order to ensure that the Project team members were adequately prepared to conduct an in-depth survey of the Knuckles canopy, all climbing members underwent rigorous training. The initial and most important phase of this training was the participation in a Basic Canopy Access Training course (BCAT) and later called Basic Canopy Access Proficiency course (BCAP). This course was created by the Global Canopy Programme, a part of the University of Oxford, Access Applications, and was conducted by a selection of experts in canopy science. It uses equipment and techniques adapted from and taught by the Industrial Rope Access Trade Association (IRATA).

Before undertaking a climb, a rigorous inspection must be made of all equipment to ensure that it is in proper working order. The Project Knuckles team has been instructed on the methods to identify whether or not equipment is compliant with health and safety regulations and, crucially, if it has been damaged since or during previous usage. During an expedition, working conditions frequently result in equipment being damaged. However, while a broken thermometer is not quite so life threatening, even a feint series of hairline fractures in canopy access equipment can pose a great ris to a user, therefore, great care must be taken in ensuring that all equipment is functioning properly and safely before it is used to suspend researchers in the air. The pre-

climb preparatory techniques taught to the Project Knuckles team during BCAT were based on *"A risk assessment for commercial arboriculture"* – a ground breaking book used for risk assessment in the arboriculture industry. It is the first manual on canopy access techniques for usage in a tropical environment.

The systems employed by BCAT use a rope system which combines both industrial rope access techniques with arboricultural practices and applies them to a scientific and frequently tropical scenario. Instead of the traditional single rope technique, BCAT uses two ropes, one on which to work, and the other on which to rely should the first rope fail. A stable tree is selected and a suitable fork is found near its main stem. The two ropes are looped through this fork, and are fed through Petzl gri gris attached by slings to a secure location on the ground at the other side of the tree. They are usually attached by the slings to another, checked and stable tree. The gri gris act as stops on the rope and can be released to allow the loop of rope to pass through them and around the tree, thus lowering the climber on the other side of the tree. Their advantage is that they can be slowly released by an operative on the ground, thus slowly lowering a researcher who is in the canopy. This can prove life saving in situations when the researcher in the air becomes incapacitated and is unable to return to the ground unaided.

The angle of the slope on which the tree is found can be a limiting factor as equipment is heavy and cumbersome and requires a clear, flat space to lay out ropes. A sturdy fork is selected and a line is inserted using a "big shot" (large catapult). This technique is chosen over other widespread methods such as line gun and cross bow insertion which carry unacceptable social risks in many parts of the world. Alternatively, with the help of a professional tree climber the line can be inserted by hand. We employed a local climber (Vajira Gajameragedara) who is highly skilled at climbing trees at rapid speed using traditional methods and who has past experience in herpetological studies, trained in the proper identification of reptile and amphibian species. He used neither ropes nor a helmet but was very proficient both in traversing the canopy branches to catch various specimens and establishing the initial line for rope systems for other researchers to ascend. The line is used to haul up two climbing ropes that are more than twice as long as the desired climbing height to allow it to be looped. Each climbing rope is secured to a nearby tree using slings.

When working in the air, the researcher must maintain two points of contact – one on each of the ropes – at all times. At any time, one of the two ropes could fail, but the chances of both failing are highly remote. To avoid any such misfortune, however, great care must be taken of the ropes, during storage, transportation and usage. They must be coiled correctly for storage, and should be kept away from grit and small stones, which could penetrate the rope's outer core and wear down the central fibres slowly, over time, without the user being aware. Sunlight has been known to damage ropes, so they must be kept in the shade whenever they are being stored.

Whilst conducting work in the canopy, helmets must be worn at all times, both by the researcher in the canopy, and by all operatives in the area immediately below the full extent of the crown of the subject tree. However, before selecting a tree, adequate steps should be taken to ensure that the given tree is in fact suitable for canopy research. The tree should be alive and healthy; researchers must check the leaves around its crown. When the crown is out of sight, checks must be made for fungi on the stem of the tree.

Trees with herpetological potential should be selected for study by examining the potential microhabitats existing around the main stem of the tree. Loose bark, epiphytes, creepers and crevices are all good reptile microhabitats and therefore give a tree potential as a useful study site. Also, trees on slopes with a steep incline should be avoided where possible, as here, manoeuvres by the ground operatives are

impaired. Ground operatives should be able to move very quickly without running should an incident occur, whereby, they either need to leave the survey site to avoid a deadly fall or they need to assist an operative suspended in the canopy.

Weather in the Knuckles was a major problem as it is often very windy and wet, especially in the cloud forest and areas with wind gaps such as Corbet's Gap where wind speeds of over 30 m s^{-1} were recorded. The canopy was not accessed under these conditions for safety reasons. It is also crucial to be aware of environmental stresses that might affect the climber. These include sunstroke, dehydration, and encounters with noxious plant materials such as the leaves of the Maossa plant (*Laportea crenulata*, of the Family Urticaceae), which was encountered on several occasions by those working on the forest floor. Rattan was found to be a problem in some areas as its sharp spikes made some trees unapproachable. This posed a threat as it held the potential to prevent or at least hinder ground rescue efforts, as they would make it difficult for ground operatives to reach the safety lifeline ropes fixed to trees.

Annex 2
Archaeology

While conducting herpetofaunal surveys during Project Knuckles 2004 and 2005, several prehistoric caves were uncovered, which were once inhabited by Mesolithic man. In these caves a possible burial chamber and artefacts of bone and quartz were discovered. One such key discovery was Gorahadigala Mesolithic caves, situated on the slopes of Dotulugala Mountain. On the floor of the main cave there was a thick ash mixture 1 metre deep, covering an area of approximately 2 x 5 metres. On notifying the relevant authorities, which included the department of archaeology at the University of Peradeniya, a small team of archaeological students under the supervision of a senior lecturer of the department joined Project Knuckles to carry out further investigations. Over a thousand artefacts consisting of vertebrate (mainly mammal) bones and several mollusc shells and crustaceans were observed on the surface, as well as tools made from stone and quartz. For further details of the artifacts see De Silva *et al.*, (2005r).

Another archaeological monument discovered was an unusual set of engravings on a large granite rock (Plate 14. Figures 1 to 4) on Kobonilagala Mountain, Loolwatte, approximately 1200m above mean sea level. Whilst further research is required, it is believed that this particular archaeological monument, on account of its size, may be an ancient burial site probably of a chieftain. For further details see De Silva *et al.*, (2005s). Further discoveries were made at Uyangamuwa lena (lena = cave) near the mountain of Lakegala (altitude 753m). The cave is situated approximately 20m above the ground on a huge granite rock (Plate 14, Figure 5). The cave contents were found to have been cleared some 50 years previously, not by prospectors, but by farmers, seeking to construct an observation shelter, probably unaware of what they were destroying (De Silva *et al.*, 2005t). During one of the visits a chart cutting / scraping tool and two Indian silver coins were discovered in an obscure corner of the cave (Plate 14, Figure 6). Further observations were made at Valagamba *lena*, Nariyagala *lena*, and Kapuruvedu oya where a stone pillar with inscriptions was found (De Silva *et al.*, 2005t).

In addition to finding these new sites, well documented and well known caves in the east of the range such as Nitre cave and Allugalena cave, were also visited. With the exception of these two caves which were explored by Davy (1821); Lawrie (1898); Sarasin and Sarasin (1908); Seligmann & Seligmann (1911), Uragoda (1973) and Deraniyagala (1992), the Knuckles have not been subjected to extensive archaeological investigations. Due to anthropogenic activities it is no longer believed that these caves hold any contents of archaeological value. The cave at Allugalena remains occupied by human residents to this day.

During the study, the Knuckles range was found to have its share of traditions, legends and folklore (Samarawickrama 2005 and De Silva *et al.*, 2005u). In particular there were many legends surrounding the folkloric King Ravana who is believed to have reigned around the1st millennium BC. However, there is neither historical nor archaeological evidence of the existence of such a king.

Conservation and recommendations

Unfortunately it was observed that many of the sites and artifacts of the area had been damaged by anthropogenic activity. Illegal construction work was in progress at Alugalena cave and Nitre Cave. Rock surfaces had been defaced by visitors and the inscribed Kapuruvedu oya stone pillar had recently been broken into pieces by opportunists who suspected it to house treasure in some form.

It is thus vital that a well designed archaeological survey be conducted in the Knuckles to locate and document any

further artefacts before they are lost due to ignorance, neglect and vandalism. Relevant authorities such as the Departments of Archaeology and Forestry should initiate a conservation management plan in order to conserve these archaeological monuments. It is also recommended that traditional lore and legends be collected and recorded for posterity, before they are lost to modern culture.It is important that residents of the Knuckles region are made aware of the historical importance of their surroundings. If managed correctly, the area has the potential to provide employment to residents through eco-tourism, which may provide an alternative source of income to those who would traditionally have relied on the forest for subsistence. Historical tourism may also prove a significant factor in the economy of the region in the future.

Annex 3

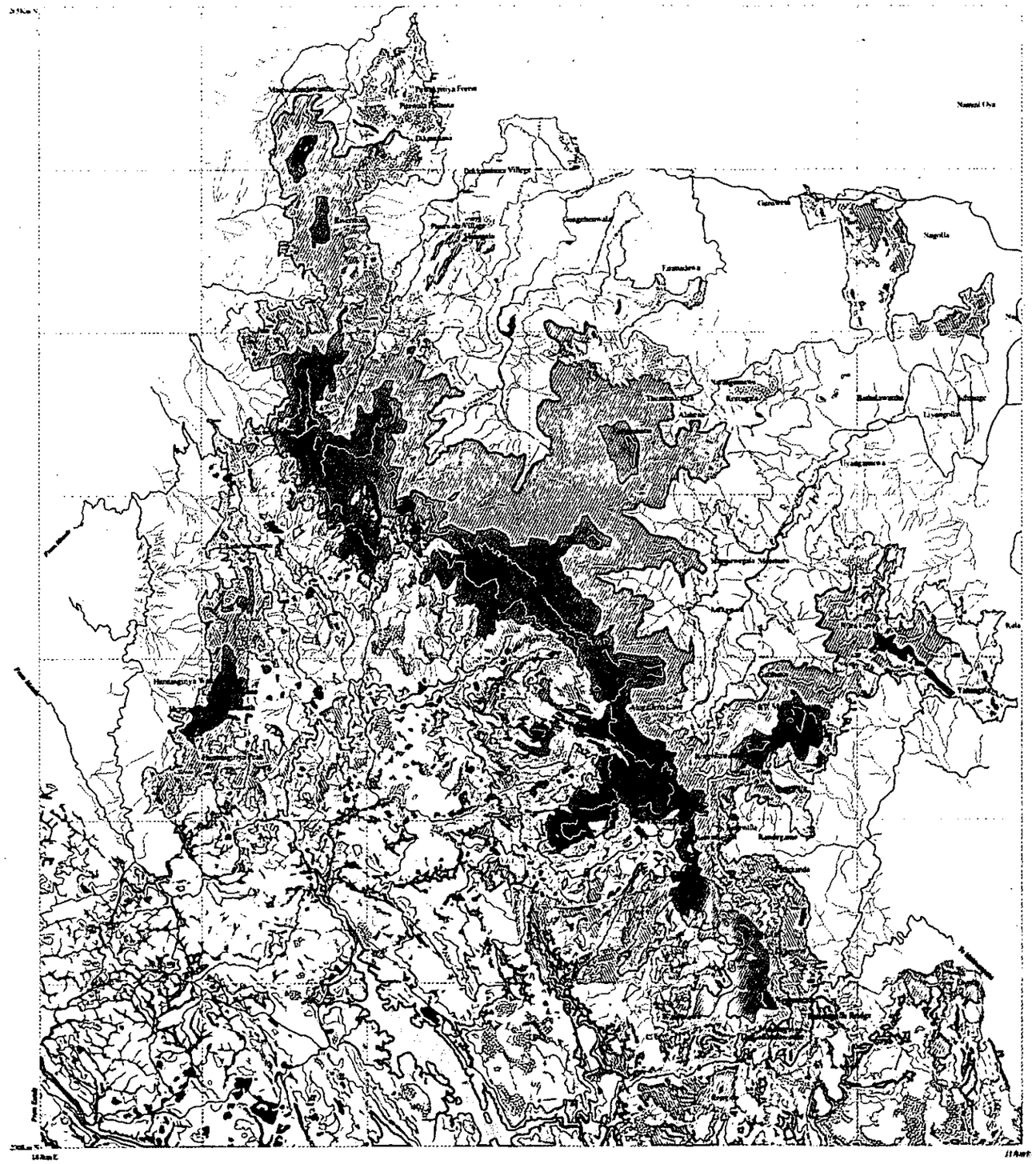
Table summarising yield (no. of individuals per species) per unit effort in the Habitats sampled in VES study. Yield = No. of individuals ÷ Effort, where Effort = time (man hours) X no. of researchers.

	Upper Montane	Lower Montane [1]	Tropical M. Evergreen	Riverine	Pine	Patana
Effort (hours)	**332**	**1096**	**1692**	**280**	**96**	**32**
Haplocercus ceylonensis		0.002737				
Ahaetulla nasuta		0.00365	0.003546			
Aspidura brachyorrhos			0.000591			
Aspidura trachyprocta	0.006024	0.00365				
Boiga ceylonensis		0.006387	0.001182			
Boiga trigonata			0.000591			
Dendrelaphis bifrenalis				0.003571		
Dendrelaphis tristis			0.001773			
Dendrelaphis caudolineoatus		0.002737				
Oligodon sublineatus		0.002737	0.002955	0.003571		
Sibynophis subpunctatus			0.000591			
Ptyas mucosa		0.001825				
Xenochrophis asperrimus				0.007143		
Xenochrophis piscator				0.003571		
Amphiesma stolatum			0.000591			
Typhlops porrectus			0.000591			
Uropeltis phillipsi		0.004562				
Uropeltis melanogaster	0.01506	0.011861		0.003571	0.03125	
Rhinophis philippinus		0.000912	0.001182	0.014286		
Hypnale hypnale		0.008212	0.008274	0.010714		
Hypnale nepa		0.00365	0.000591			
Trimeresurus trigonocephalus		0.004562	0.001182			
Varanus bengalensis			0.002364			
Calotes calotes	0.012048	0.008212	0.01182		0.010417	
Calotes ceylonensis			0.00591	0.007143		
Calotes liocephalus	0.060241	0.007299	0.000591			
Calotes liolepis	0.003012	0.012774	0.007092	0.003571	0.0625	0.0625
Calotes versicolor		0.006387	0.010047	0.003571	0.010417	0.34375
Ceratophora tennentii	0.021084	0.279197		0.096429		
Cophotis ceylanica		0.007299				
Lyriocephalus scutatus		0.007299	0.007683			
Otocryptis wiegmanni		0.040146	0.034279	0.007143	0.010417	
Otocryptis nigristigma		0.000912	0.020686	0.035714		
Cnemaspis scalpensis	0.003012	0.001825	0.004728			
Cnemaspis kandiana		0.017336	0.001773	0.025		
Cnemaspis podihuna			0.000591			
Cnemaspis tropidogaster		0.00365	0.005319			0.0625
Cyrtodactylus soba	0.01506	0.025547	0.004728		0.020833	
Geckoella triedrus		0.034672	0.017139	0.007143	0.03125	
Hemidactylus brooki parvimaculatus		0.000912	0.001773			
Hemidactylus depressus		0.000912	0.008865	0.017857		
Hemidactylus frenatus			0.001773			
Hemidactylus triedrus lankae			0.000591			
Chalcidoseps thwaitesii		0.033759	0.018913			
Dasia halianus		0.000912				
Lankascincus deraniyagalae			0.002955			
Lankascincus fallax		0.019161	0.021277	0.085714	0.010417	
Lankascincus gansi		0.001825				
Lankascincus taprobanensis	0.003012	0.011861	0.001182	0.003571		
Lankascincus taylori		0.009124	0.008274	0.010714		
Lygosoma punctatus		0.002737				0.1875
Mabuya beddomi		0.000912	0.000591			
Mabuya carinata			0.008274	0.003571		
Mabuya macularius		0.002737	0.002364	0.007143		
Nessia bipes		0.025547	0.005319	0.003571		
Nessia sarasinorum			0.002955			

[1] includes Disturbed Lower Montane Rainforest ie active and abandoned cardamom plantations.

NB Above calculated only to specimens whose species was identified ie excludes *Cnemaspis sps.* Etc.

Plate R18 - Land use Map of Knuckles conservation area



LEGEND

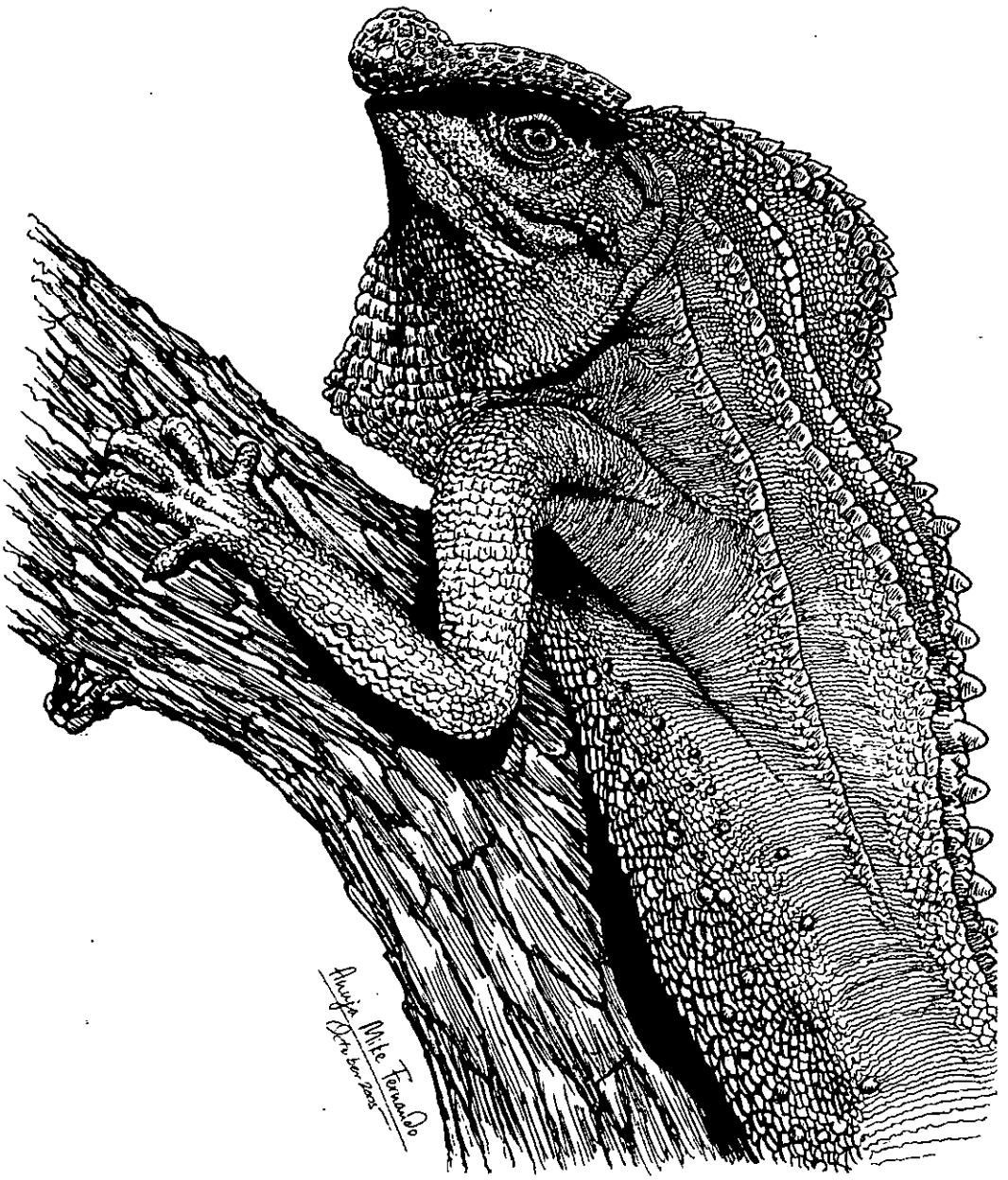
- Natural Woodland (Open)
- Tropical Mixed Evergreen Forest (<800m)
- Lower Montane Forest (800-1300m)
- Upper Montane Forest (>1300m)
- Paddy
- Scrub
- Grassland
- Settlement
- Plantation
- Rock
- Water
- Peak
- Main Road
- Stream
- Contour
- Knuckles Conservation Area Boundary

SECTION 2.

PUBLICATIONS ENSUING FROM KNUCKLES EXPEDITION 2004 AND 2005

(Published in *Lyriocephalus* Vol. 6 (1 & 2). ISSN 1391-0833
13 to 206 (original page numbering in the journal).

Sketch of *Lyriocephalus scutatus*



The Diversity of the Dumbara Mountains (The Knuckles Massif, Sri Lanka): With special reference to its herpetofauna.
Lyriocephalus Special issue, 2005 November, Volume 6 Numbers 1 & 2: 13-33
ISSN 1391–0833

THE DIVERSITY OF THE KNUCKLES ECOSYSTEM: WITH SPECIAL REFERENCE TO ITS HERPETOFAUNA

Anslem de Silva[1], A. M. Bauer[2], C. C. Austin[3], S. Goonewardene[4], J. Drake[4], P. de Silva[1], M.G.T.H. Aberathna[5], Tharanga Dassanayaka[5], G. S. Samarawickrama[6], R.D.C.S.K.Dasanayaka[7], A.M.R.K. Amarakoon[7] & M. M. Goonasekera[7]

[1]15/1 Dolosbage road, Gampola, Sri Lanka. Email: kalds@sltnet.lk
[2]Department of Biology, Villanova University, 800 Lancaster Avenue, Villanova, Pennsylvania 19085, USA. Email: aaron.bauer@villanova.edu
[3]Museum of Natural Science, Louisiana State University, 119 Foster Hall, Baton Rouge, LA 70803 USA. Email: ccaustin@lsu.edu
[4]97, Battersea Park Road, London, SW9 4DU, UK. E-mail: hsr.wild@gmail.com (University of Edinburgh, UK)
[4]Creagard, Isle of Mull, PA75 6RA, UK. E-mail: jfdrake@gmail.com (University of Edinburgh, UK)
[5] Dept of Zoology, University of Sri Jayewardenepura, Nugegoda, Sri Lanka
[6]Dept. of Archeology, University of Peradeniya, Sri Lanka
[7]Dept of Biological Sciences, Faculty of Applied Sciences, Rajarata University of Sri Lanka.

Key wards: Knuckles, Dumbara kanduwetiya, biodiversity, threats, conservation.

Introduction

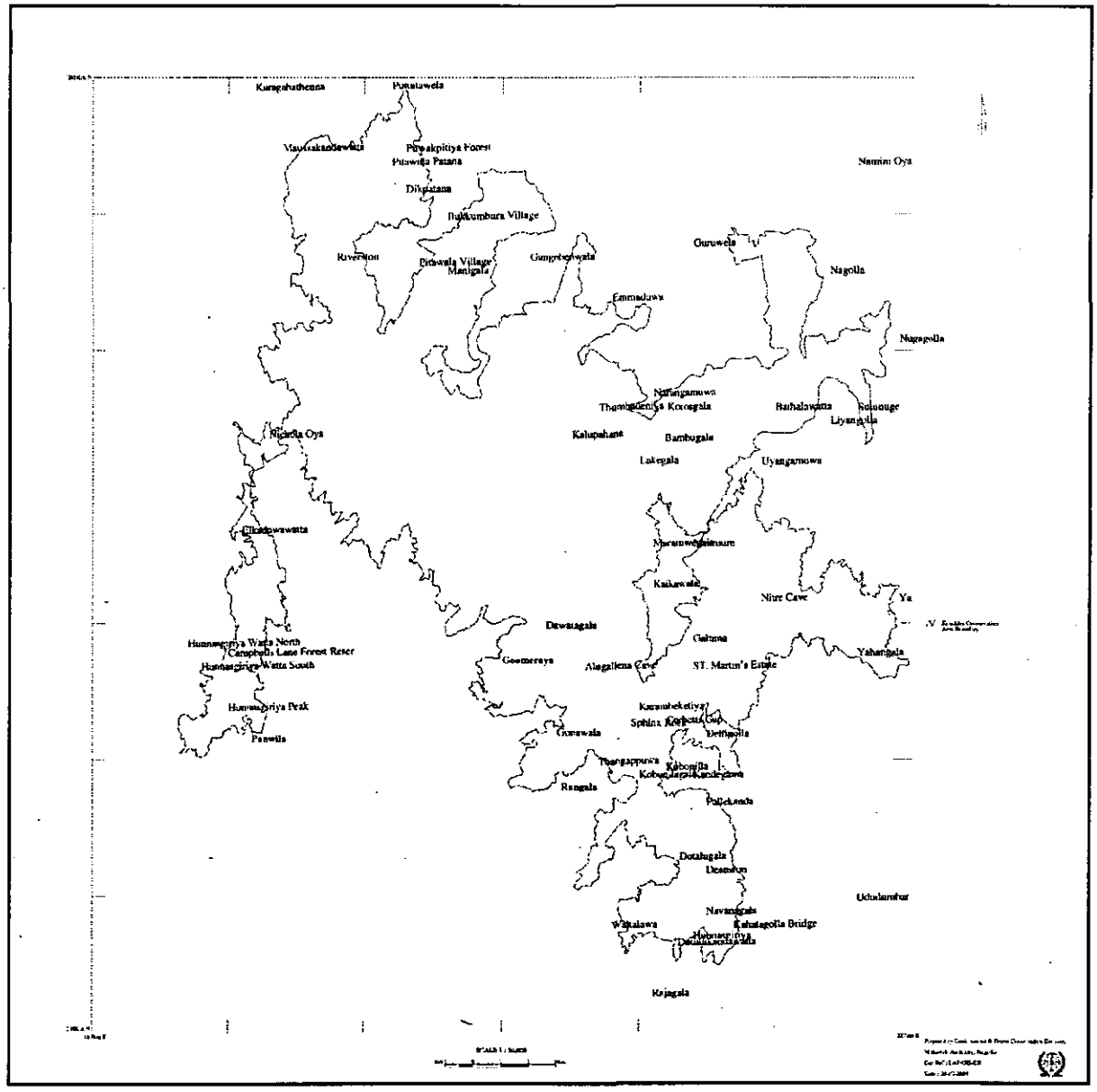
The Dumbara hills or the Knuckles Massif with its 'Cloud Forests' are categorized as a separate Floristic Region of the country (Ashton & Gunatilleke 1987). In terms of watershed, the Knuckles forest is considered the second most important forest an important watershed for the River Mahaweli (Giragama & Madduma Bandara, 1993). Furthermore, the Knuckles Massif harbours many geological features, forests, fauna, historical and archaeological aspects peculiar to the area. The 35 distinctly rugged mountain peaks, some covered with pristine cloud forests, are considered to contain the most scenic and breathtaking landscapes in the hill country.

The area is steeped in history. Archaeological evidence found in the region suggests that Mesolithic man once inhabited some of the rock caves in the Knuckles range (see de Silva, *et al.*, 2005 in this volume). Furthermore, tradition and folklore indicate that the mountain Lakegala and its environs belonged to the kingdom of the legendary king Ravana.

The objectives of the present survey were: to record and identify the herpetofaunal species inhabiting the Knuckles Mountains (Figure.1); to assess their relative abundance, population status, interspecies associations, habitat features and distribution within the Massif; and to identify the threats posed to these animals and their habitats. In addition, we aim to make recommendations regarding future research directions and management of the ecosystems of the Knuckles utilizing the data collected from the survey.

In this introductory paper, we wish to record in brief some of the major aspects of the Knuckles Massif such as its geology, vegetation, fauna, history and archeology. Subsequent papers deal in detail with more specific aspects of the herpetofauna inhabiting the Knuckles Massif.

Figure 1.
Locations Sampled at Knuckles Ecosystem



Origin of the name 'Knuckles'

It appears that there is some mixed opinion / controversy over the usage of the local name 'Dumbara Kanduwetiya' or Mitiyawatha' over the alien English name "Knuckles". The late P. G. Cooray (Plate 1. Figure 1), a well-known geologist and author of a comprehensive book on the Knuckles, discusses this subject in some detail (Cooray 1998). Cooray was also the team leader of the first Knuckles Expedition in 1956, and the author of many subsequent papers on the region (see A bibliography of literature on Knuckles by de Silva 2005 in this volume). In the present paper, we wish to discuss the various names used for this ecosystem as well as for some parts of the Knuckles.

Cooray (1998) is of the opinion that it was the early British surveyors who named the five distinct peaks as the "Knuckles" as they resembled the knuckles of a clenched fist (Plate 1 Figure. 2). However, from Skeen's (1868) work it suggests that it may have been Lieutenant General John Fraser (Plate 1 Figure 3), who named the peaks "Knuckles" when he compiled the first one mile to one inch scale map of the mountain zone of Sri Lanka. John Fraser was also appointed as the Director of Island Works in 1819 a post, which he held until 1832 and subsequently as the Surveyor General from 1837 to 1840. Frazer is also well known for the first detailed map of Ceylon that was published by Arrowsmith, England.

It is also thought that the name Knuckles originated from Ebert Knuckle: a German who had been operating a clandestine radio station in the Knuckles. A group of English army soldiers lead by Bray ambushed him and took him prisoner. This note was documented in a diary kept by Bray (Peiris 1988).

During the literature search to compile the bibliography (de Silva 2005 in this volume), we came across several publications, (some nearly 150 years old) referring to the name Knuckles. Two of the earliest were the well-known *Gazetteer* of 1859 by A. M. Ferguson and a book on the Knuckles itself *The Knuckles and other poems* by W. Skeen published by the author in Colombo in 1868. Furthermore, the survey department was well established in Sri Lanka by 1800, but during a search of old survey maps and other records maintained at the department we could not locate the name of the surveyor who first assigned the name 'the Knuckles'. It could only be ascertained that the name "the Knuckles" would have been proposed at some point between 1830 and 1850.

Other names given to Knuckles

Available literature uses various names for this mountain range. Thus, we wish to define these various names in this introductory paper.

Dumbara Kanduvetiya

This well know Sinhalese name: Dumbara Kanduwetiya saha Mitiyawatha, refers to the entire Knuckles range of mountains including its valleys. In Sinhalese: Dum = smoke or clouds or mist and bara = heavy or laden and Kanduwetiya = mountain range and Mitiyawatha = valley.

The Knuckles District

According to Skeen (1868), the Committee of the Planters' Association in 1856 defined the Knuckles district proper as bounded in the north by the Hoolankanda and the Knuckles ridge; in the east by the Knuckles range; in the south by the Kottaganga; and in the west by the Hoolanganga.

The Knuckles Massif

This refers to the detached mountain mass (covering an area of 234 sq km of peaks over 915 m) of the Central Highlands bounded by the Dumbara valley (with the Mahaweli river) to the south and east, and by the Matale valley to the west. Elsie Cook (Plate 1 Figure 4), a geography lecturer at University College, Colombo (present day University of Colombo) first proposed the name "Knuckles Massif" in 1931 (Cooray 1998).

The Knuckles Man and Biosphere Reserve

In 1969 under the auspices of UNESCO, the National Science Council (present National

Science Foundation) formed a committee, selected several areas of natural and planted forests and declared them "Man and the Biosphere" (MAB) Reserves. Under this programme, Dotulugala mountain (elevation 1548 m, the fourth highest peak of the range with an area of 1600 hectares) was declared as a Man and Biosphere reserve (MAB) in 1975 (Sri Bharathie, 1979).

The Knuckles Conservation Forest
The Knuckles Conservation Forest refers to an area of 17.500 ha of the Knuckles mountain range above 1,067 m (3,500 ft). Details of the boundaries are given in Gazette No. 1130/22 of 5th May 2000.

On the recommendations made by an expert committee, a Cabinet decision was taken in 1985 that the Knuckles range should be conserved. Thus, in June 1988 a workshop organised by the Forest Department and the IUCN was held in Kandy for the preparation of a conservation plan for the Knuckles. The Government of Sri Lanka decided that the area above 1, 067 m (3,500 ft) in the Knuckles mountain range should be identified as "The Knuckles Conservation Forest". Thus on 5th May 2000, the Government declared an extent of 17.500 ha of the Knuckles range of mountains above 1,067 m by Gazette Extraordinary No. 1130/22 as "The Knuckles conservation forest" (Gazette 2000).

The Knuckles Range
This refers to the western part of the massif which runs from north-northwest to south-southeast across Rangala at an elevation of 1220 m of which the highest peak is Gombaniya 1906 m (Cooray 1998).

The Knuckles Peaks
This refers to approximately 35 or more peaks rising from about 915 m in the Knuckles. Of these, the tallest is Gombaniya at 1906 m and the most spectacular, is Lakegala at 1319 m (see the cover illustration).

Campbell's Land forest reserve
Until recently, this area of 290 ha was the only protected part of the Knuckles region.

The Knuckles Massif
The Knuckles Massif is complex both physiographically and structurally. The terrain of the Knuckles Massif is rugged, with several prominent peaks varying from 900 to 1900 m. It is situated at N7° 21' and E81° 45' in the central province and falls within the Kandy and Matale administrative districts. The type of rock according to Cooray (1961) is pre-Cambrian Vijayan Complex. The soils are mostly lateritic.

Climate
Three distinct climatic zones based on rainfall and vegetation are identified from the country; namely wet, dry and intermediate. The dry, wet and the intermediate zones constitute 65%, 23%, and 12% respectively of the island's total land area (IIED, 1992).

The Knuckles Massif is located at right angles to the two principal wind currents which bring the rains (Southwest Monsoon and the Northeast Monsoon) to the country. It acts as a climatic barrier and thus has a high rainfall, especially during the northeast monsoonal winds between November and February. As the Knuckles is situated on the boundary of the wet and dry climatic zones its resulting climate ranges from extreme wet on the southwestern slopes of the mountain to dry and warm on the eastern side.

The average annual rain fall varies from 2540 mm to 5000 mm. The maximum daily temperature ranges from 18 to 21 ° C. Also there is drop in the temperature by one degree centigrade for every 160 m increase in elevation (IUCN & Forest, 1994).

The Knuckles with its 510 streams is given a stream rank rating of 1 (IUCN & World Conservation Monitoring Centre 1997).The range is the source of many rivers and streams, which include the Heen ganga, Hulu ganga, Mimure oya and Lailawella oya. It also forms a critical watershed area

for the Mahaweli Ganga – Sri Lanka's principal river.

The 'Cloud Forests' of the range derive themselves from the layer of cloud which forms around the mountains at high altitudes. When it meets the mountain surface, it forms a 'diurnal fog', a reservoir of airborne moisture. This humidifying agent also keeps the local environmental temperature low, thus allowing for a very different ecosystem to develop.

Vegetation

The forests in the Knuckles Massif cover an extent of around 20,000 ha. However, much of these were reduced initially by the British for coffee in the early 19th century, and later for tea, chinchona and more recently for cardamom plantations (Nanayakkara, 1988). For further details on vegetation see Ratnayake (2005) in this volume, de Rosayro, 1956 and Nanayakkara, 1988. The vegetation consists of the following distinct vegitational habitats

1. Humid tropical lowland semi-evergreen forests
2. Tropical sub-montane humid semi-evergreen forests
3. Tropical montane humid evergreen forests
4. Montane grasslands
5. Pygmy or elfin forests

However, during the survey we considered the following vegetation types as distinct and carried out our sampling.

1. Upper Montane Forest (Plate 1. Figure 5).
2. Sub montane forests
3. Lowland semi-evergreen forests
4. Riverine forests (Plate 1. Figure 6)
5. Elfin or pygmy forests (we considered Elfin forests as a constituent part of Montane Forests)
6. Savannah
7. Monoculture (pine, acacia, cardamom etc) plantations (Plate 1. Figure 7),
8. Anthropogenic agro ecological environments (paddy fields, home gardens)

By the year 1990 the Knuckles Conservation area had 1,173 ha of *Pines* species and 158 ha of Acacia (*Acacia mengium*) raised by the forest department (IUCN & Forest, 1994).

Historical and archaeological aspects

There are several Mesolithic caves scattered throughout the Knuckles Massif, which have been inhabited by early cave dwellers (see de Silva *et al.*, 2005r in this volume). Of these the most well known are Nitre cave and Alu-gallena cave. There are also remains of other monuments of archaeological interest, suggesting the importance of Knuckles as an archaeological and historical site.

Human settlements around the Knuckles

Presently, there are 77 villages in the proximity of the Knuckles conservation area (IUCN & Forest, 1994). According to Abeygunawardena. & Vincent (1993) there are 9 villages above the 1050 m contour. However, during July & August 2004 and 2005 we observed the construction of several new houses and hotel complexes in the Knuckles.

Conservation & Legal aspects

We learn from the classic 17th century work of Robert Knox (1681) and even John Davy's book (1821) about the abundance of thick forests in the central highlands of Sri Lanka where the jurisdiction of the kings ensured their protection. According to Knox (1681), there were even watchers in these forests. The king's command was that "none may fell" these trees, as the thick forests acted as a natural barrier for any invading army.

The British Government of Ceylon (Sri Lanka) first declared the area above 1562 m elevation as a climatic reserve in 1873. By 1902, approximately 290 ha of Knuckles had been declared as a forest reserve (Gunawardana 2003). But it was not until almost a century later, in 5th May 2000, that the Government declared an extent of 17.500 ha of the Knuckles range of

mountains above 1,067 m as "The Knuckles Conservation Forest" by a Gazette Extraordinary – number 1130/22 (Gazette 2000).

In the same year, the area was declared a National Man and Biosphere Reserve and the Forest Department is currently planning to propose the forest a both an International Man and Biosphere Reserve and a Natural World Heritage Site.

Field methods

The study was conducted during the periods of the 25th June, 2004 to the 20th August 2004, and from the 14th July to the 30th September 2005. In addition one of the authors (AdS) has been visiting the Knuckles during the past 20 years.

1. The field map used was the "Land use map of Knuckles Conservation area" compiled by Natural Resources Management Services, Polgolla. Prepared in 2004 (Map 1). In addition, maps compiled by the Survey Department were also used.

2. Four main survey techniques used were: visual encounter surveys (VES), patch sampling, canopy sampling and sampling in large (20 x 20 m) leaf litter quadrats in different vegetation habitats.

3. In canopy sampling the following tools were taken by the person who climbed trees: penlight torch, measuring tape, flexible probe to check tree holes, pH strips, digital thermometer, hand axe to widen tree holes if required, and a cloth bag tied to a 15 m long nylon rope.

4. The coordinates of all study sites, including the altitude, were recorded using a GPS instrument. The temperature and relative humidity was recorded using Max-Min thermo hygrometer and digital thermometer.

5. Soil hardness was measured using a penetrometer.

6. The external body temperature of animals was recorded by lightly touching them with the 130 mm long stainless steel sensor probe of a digital thermometer (stainless steel sensor probe model ST-9263A/B/C), taking care not to disturb the animal. The animal was then captured gently by hand and, with minimal handling, the stainless steel sensor probe of the digital thermometer was inserted into the cloaca to record the internal bodily temperature.

7. Immediately after taking the cloacal temperature, a stool sample was collected into a plastic vial containing 10% formaldehyde solution. A filed number was written on the surface of the vial for identification. These were later sent to the Parasitology section of the Faculty of Veterinary Studies at the University of Peradeniya for parasitological investigations.

8. Each specimen had its species identified (when possible), in addition to the gender of the animal, length from the tip of the snout to the vent (SVL), and tail length, recorded in millimetres using a micromatic 1 m steel tape. Reproductive status (gravid or not), presence of ecto-parasites and physical defects (missing tail tip etc) if observed were also recorded in a structured survey form.

9. Stomach contents were obtained from randomly selected animals for analysis. Distilled water was gently squirted into the stomach through an intragastric canula, while the mouth of the animal was held downwards, thereby flushing out the stomach contents, which were collected into sterile bottles. The stomach contents were preserved in 10% formaldehyde and examined in the laboratory under a dissecting microscope.

10. The animals were released back to their original place of capture after measuring and sampling.

11. Botanical specimens obtained were identified at the Herbarium, Royal Botanical Gardens, Peradeniya or through the use of manuals. Additionally, the works of Ashton *et al.* (1997) were used.

12. Observations were recorded of amphibians and reptiles run over and killed by road traffic in the roads of the Knuckles Massif.

13. Voucher specimens of geckos and skinks (male and female, usually a single specimen) were collected for taxonomical investigations (with the approval from the Departments of Wildlife Conservation (DWLC) and Forest for Anslem de Silva, A. Bauer & C. Austin).

14. All the species of amphibians, reptiles, invertebrates and parasites collected and habitats (terrestrial and lentic) were photographed using an Olympus OM 30 camera using macro and close-up lenses. Fuji Chrome and Fuji Colour, 400, 200 and 100 ASA, 36 exposure films were used.

15. Data was analysed using the statistical package Minitab for basic statistical analysis, ANOVA and Anderson – Darling normality tests.

Results

Vertebrate Fauna

Amphibians

During the survey 28 species of amphibians were observed (Table 1 and refer de Silva *et al.*, 2005o in this volume). However, we feel that a more detailed survey should be conducted in the Knuckles to investigate the amphibian fauna.

Reptiles

During the survey 75 species of agamids, skinks, geckos, varanids, chelonians and snakes were observed (Table 2 & 3 and refer de Silva *et al.*, 2005c; de Silva *et al.*, 2005h, de Silva *et al.*, 2005k and de Silva *et al.*, 2005n in this volume).

Birds

During the survey, 81 species of bird were observed (annexure 1).

Mammals

During the survey, 23 species of mammal were observed (annexure 2).

Invertebrate fauna

During the expedition, several species of spiders, butterflies, crabs and land and aquatic snails were observed but these were not collected nor recorded as it was not within the scope of the project. We feel that an extensive study should be initiated to investigate the invertebrate fauna of the Knuckles. We observed several species of land and aquatic snails were observed during the survey (annexure 3). Shells of dead snails were investigated for identification purposes (see de Silva *et al.*, 2005q in this volume)

Threats

The following threats all mainly caused by humans were observed in the ecosystems of the Knuckles:

a) Climate Change

Studies on the annual rainfall of the Knuckles Range have shown a decrease around Kobonila and Madugoda (Giragama & Madduma Bandara, 1993).

b) Plantations

The biggest threat is due to deforestation and alteration of natural forests for plantations (Coffee, tea, and cardamom, see annexure 4 for notes on these plantations).

Studies on the cardamom cultivation in the Knuckles Range have shown that:

1. Cardamom cultivation discourages the growth and regeneration of forest plants.
2. Soil characteristics in the cardamom plots and the natural forest show that the 'A' horizon is well preserved in the natural forest with a depth of 30 to 35 cm and a good mulch layer, whilst in cardamom the 'A' horizon was relatively low, at around 15 to 25 cm deep. The moisture content in cardamom areas

was also low (Navaratne & Madduma Bandara, 1993).

3. Soil moisture content in a natural forest area is around 50 to 60 percent whilst in cardamom cultivated soil it has been recorded at around 15 to 25 percent (Ramakrisnan & Nvaratne, 1992). Rain water retention capacity has also been reduced in cardamom areas. Soil erosion was also common in cardamom areas (Plate 1 Figure 8).

A further study of the plant and soil characteristics of natural forest and cardamom cultivation around Thangappuwa and Corbet's Gap has shown that:

1. There were significantly less smaller trees in areas of cardamom cultivations.
2. Litter measurements have shown higher nutrition, more clay and organic mater value in natural forest than in areas of cardamom cultivation (Navaratne & Madduma Bandara, 1995).

Although Sri Lanka harbours appreciable numbers of reptile species, as evident from our recent survey in the Knuckles, we do not know how many species may have become extinct with the clearing of virgin rain forests and other forests. Gans (1973) considers the possibility that some species failed to make the transition and became extinct as the forests shrank. For amphibians Pethiyagoda & Manamendra-Arachchi have shown that approximately 18 amphibian species are already extinct (Stuart *et al.*, 2004).

Predators of herpetofauna

As a result of diminishing natural habitats presently in the Knuckles, many reptiles have adapted to live in anthropogenic habitats (including inside houses) and plantations. These include *Lankascincus* species, *Cyrtodactylus soba, Geckoella triadrus, Calotes liolepis, Otocryptis wiegmanni* and *Uropeltis melanogaster.* However, these reptiles are over-exposed to predators such as such as domestic cats, poultry, ants and the common coucal (*Centropus sinensis*) which are common and on the increase in terms of numbers in the Knuckles. However, Skeen (1858) reports that livestock was not numerous. Perhaps Skeen (1858) would have meant poultry, goats, cattle etc.

Population growth and human settlement

Even during the survey period we observed several hectares of land cleared, and several further hectares of land set on fire (Plate 9 Figure 7) for various human activities in many places along the boundary of the buffer zone. Also while a bulldozer was preparing land for a road development, we observed one Uropeltid and a Nessia having been killed. This is just one random observation. Over seventy villages are located in the periphery of the forest. A study by Kankanamge & Gunatilake (1993) has shown that the people in these villages have a high degree of dependency on the forest. This study also demonstrated that a high dependency on forest resources is reduces with increases in income, particularly if that income comes from non-forest related products.

Forest fires

Several hundred hectares of forest and grassland are set on fire annually in the Knuckles Range. Between June and August, 2004 and between May and June 2005 we observed several such fires which killed a number of (deleted where it said many hectares as this is said above) animals (Plate 9 Figure 8). These fires may pose a serious threat not only to herpetofauna and their eggs which are laid in leaf litter, but also to their prey species.

Agrochemical use

We observed that due to a collapse in tea planting in the Knuckles, earlier tea estate labourers living on the boundary as well as within the conservation area have started to grow vegetables and keep goats. Pesticides and nitrogen fertilizers are used by these people, the long term effects of which are yet to be investigated.

Road kills

During the survey (2004 and 2005) we observed the following animals run over and killed by road traffic.

1. *Calotes liocephalus* (Plate 2 Figure 8)
2. *Calotes liolepis*
3. Many specimens of *Calotes calotes* and *C. versicolor*
4. One *Boiga ceylonensis*
5. One *Coeloganthus helena*
6. Several killed amphibians were observed during the night

However, these were random observations. We feel that if daily checks were made on the roads of the Knuckles, particularly between Hunnasgiriya and Kaikawela along the Mimure road more road kills will be observed.

Killing of snakes

During the survey we observed *Boiga ceylonensis, Bungarus ceylonicus, Lycodon aulicus* and *Dendrelaphis tristis* which had been killed by people living around the conservation border.

Discussion and recommendations

The Knuckles Range is an important refuge not only for relict and endemic species of reptiles and amphibians, but also for land snails, fish, crabs, birds and plants. Crusz (1984) considers that the montane forests of Sri Lanka contain the most distinctive and conservative elements of the Sri Lankan reptile and amphibian fauna which have been least influenced by recent biological invasions from the Indian mainland. Furthermore, Sri Lanka possesses a much higher number of relict reptile forms than continental South India (Crusz, 1984; Senanayake, Soule & Senner, 1977; de Silva, 2001), with recent molecular studies of some amphibians and *Uropeltidae* snakes confirming that Sri Lanka has maintained fauna quite distinct from that of the Indian Mainland (Bossuyt *et. al.*, 2004). The Knuckles range could be stated as an ideal example of one of the country's least influenced ecosystems with many endemic and relict species.

According to published sources, up to now a total of 95 amphibian species and 185 reptile species have been reported in Sri Lanka (Batuwita & Bahir, 2005; Bahir & Silva, 2005; Das & de Silva, 2005; Deraniyagala, 1953, 1955; de Silva, 2001, Dutta & Manamendra-Arachchi, 1996; Manamendra-Arachchi & Pethiyagoda. 2005; Meegaskumbura & Manamendra-Arachchi 2005; Gans & Fetcho, 1982; Greer, 1991; Pethiyagoda & Manamendra-Arachchi, 1998; Smith,1931, 1935, 1943 and Taylor, 1950, 1953 etc.). Among the amphibians and reptiles inhabiting the Knuckles, 11 endemic genera (*Nannophrys, Lankanectes, Adenomus, Chalcidoseps, Lankascincus, Nessia, Ceratophora, Cophotis, Lyriocephalus, Aspidura,* and *Haplocercus*) were observed during the survey. Other researchers have observed relict species such as *Balanophis, Cercaspis* and *Pseudotyphlops* (Table 1) (Bambaradeniya & Ekanayake, 2003). However, during our survey we could not locate representative species of these genera.

However, it is evident that some of these reptiles and amphibians face many threats in the Knuckles such as the daily threat of road traffic which in fact this appears common in many parts of Sri Lanka (Bambaradeniya *et al.*, 2001; de Silva 2001, 2003). Furthermore, during our (AdS, AB & CA) ongoing island wide surveys we have encountered reptiles such as the pythons, star tortoise, terrapins, other snakes and lizards and amphibians are run over and killed by road traffic during every field trip. In addition, many colleagues from different parts of the island have informed us of several further road kills which occur regularly, including mortality incidents of juvenile crocodiles. Thus, road traffic kills are an important threat which needs to be addressed immediately.

Snakes, venomous and non-venomous are widely killed throughout Sri Lanka through fear, ignorance and as a precautionary measure against snakebites. The high incidence of snakebite morbidity and mortality in Sri Lanka is the major contributory factor for this attitude (de Silva, 1981 & 1982). Furthermore, a host of other snakes such as the Trinket snake (*Coeloganthus helena*), common kukri snake

(*Oligodon arnensis*), cat snakes (*Boiga ceylonensis and B. trigonata*), the Hump nosed viper (*Hypnale hypnale) and* green pit viper (*Trimeresurus trigonocephalus*) were found to have been purposefully killed by humans, mainly during clearing forests.

Specific proposals:

1. The catastrophic mortality of *Cophotis ceylanica* observed in 1992 around Hakgala and Nuwara Eliya where hundreds were found dead within a few days did not receive due attention from relevant authorities. Hence, establishing a vigilant veterinary unit attached to the Department of Wildlife and Conservation is suggested. They should be able to take immediate measures in such instances.

2. Initiate training for veterinarians on the management of all reptiles and amphibians – this could be taken up during undergraduate period or a special training for veterinarians attached to the Dept. Of Wildlife Conservation.

3. As data on the distribution and ecology of the majority of the reptiles and amphibian species of the country is scarce, properly designed studies to gather such information are urgently required. It is on the basis of such studies that warnings could be given in the future (Crusz, 1973).

4. Declaring smaller pocketed forests with high biodiversity as strict natural reserves. They could also serve as school "field laboratories"; to be managed and protected by local school children under the supervision of NGO's in the particular area. These could also be for research purposes by suitable organisations.

5. Captive breeding of and genetic research on Endangered or Critically Endangered taxa need high priority. Conservation breeding programs should be initiated when wild populations are still in their thousands (1990 IUCN Red List). Immediate action should be initiated as regards the endemic agamids of Sri Lanka such as some species of *Ceratophora* and *Calotes*, for example in addition to a growing number of amphibian species.

6. Conduct awareness programs amongst the residents of the buffer zone on the importance of the fauna and flora of the buffer zone, home gardens and core area of the Knuckles.

7. Immediate studies to identify the predators of reptiles and amphibians should be carried out and appropriate action should be taken. For example: measures such as monitoring poultry and domestic cats which predate on large number of reptiles and amphibians. This needs immediate controlling.

8. Encourage farmers to employ organic farming methods instead of using insecticides and artificial fertilizers.

9. Study traditional beliefs and practices regarding amphibians and reptiles to enable the utilization of some of these beliefs in public awareness programs. This should hopefully reduce the rate of unnecessary killing of these animals. For example, it is widely believed in traditional households that if a cobra comes into a house it could be a departed family member reincarnated as a cobra and therefore should not be killed. Similarly, geckos are not killed, as it is believed that they are indicators of either good or bad luck. The flesh and fat of *Varanis salvator* is considered highly poisonous, due to the scavenging habits of the water monitor, which has contributed to its survival in appreciable numbers even today.

10. Conduct a survey on the road kills in

the Knuckles, establish areas of high risk area and take adequate precautions such as the erection of road humps and caution signs.

Literature cited

Abeygunawrdena, P. & J. R. Vincent. 1993. Bare Knuckles: fighting deforestation in Sri Lanka. *Harvard Institute for International Development*, Spring 1993: 1-17.

Ashton, M. S. & C. V. S. Gunatilleke. 1987. New light on the plant geography of Ceylon. 1- Historical plant geography. *Journal of Biogeography*, 14: 249-285.

Ashton, M. S., S. Gunatilleke, N.de Zoysa, M..D. Dassanayake, N. Gunatilleke and S. Wijesundera. 1997. *A field guide to the common trees and shrubs of Sri Lanka.* WHT Publications (Pvt.) Limited, 430 pp.

Bahir, M. M. & A. Silva. 2005. *Otocryptis nigristigma*, a new species of agamid lizard from Sri Lanka. In: Yeo, D. C. J., P. K. L. Ng & R. Pethiyagoda (eds.), Contributions to biodiversity exploration and research in Sri Lanka. *The Raffles Bulletin of Zoology*, 12, 235-241.

Bahir, M. M. & K. P. Maduwage (2005). *Calotes desilvai*, a new agamid lizard from Morningside Forest, Sri Lanka. In: Yeo, D. C. J., P. K. L. Ng & R. Pethiyagoda (eds.), Contributions to biodiversity exploration and research in Sri Lanka. *The Raffles Bulletin of Zoology*, 12, 134-150.

Bambaradeniya, C. N. B., J. M. Wickramasinge, V. A. P. Samarawickrama & L. D. C. B. Kekulandala. 2001. Herpetofaunal mortality in highways: a case study from Sri Lanka. *Abstracts Fourth World Congress of Herpetology*. Pp 10-11

Bambaradeniya, C. N. B., & S. P. Ekanayake. 2003 *A Guide to the Biodiversity of the Knuckles Forest Region.* IUCN, Sri Lanka Country Office, Colombo. 68 pp.

Batuwita, S. & M. M. Bahir, 2005. Description of five new species of Cyrtodactylus (Reptilia: Gekkonidae) from Sri Lanka. In: Yeo, D. C. J., P. K. L. Ng & R. Pethiyagoda (eds.), Contributions to biodiversity exploration and research in Sri Lanka. *The Raffles Bulletin of Zoology*, Supplement No. 12: 351–380. in press

Bossuyt, F., M. Meegaskumbura, N. Beenaerts, D. Gower, R, Pethiyagoda, K. Roelants, A. Mannaert, M. Wilson, M. Bahir, K. Manmendra-Arachchi, P. K. L. Ng. C. Schneider, O. V. Oommen & M. C. Milinkovitch. 2004. Local endemism within the Western Ghats-Sri Lanka biodiversity hotspot. *Science.*, Volume 306. 479-481.

Cooray, P. G. 1961. *Geology of the country around Rangala.* Geological Survey Department of Mineralogy, Government Press, Colombo 7-16.

Cooray, P. G. 1998. *The Knuckles massif – a portfolio.* Forest Department, Sri Lanka. 75 pp.

Crusz, H. 1984. Parasites of endemic and relict vertebrates: a biogeographical review, IN: *Ecology and Biogeography in Sri Lanka*, Ed. Fernando, C.H., Dr. W. Junk Publishers, The Hague; 321-351.

Davy, J. 1821. *An Account of the Interior of Ceylon and of its Inhabitants with Travels in that Island.* Longman, Hurst, Rees, Orme & Brown London. 530 pp.

de Rosayro, R. A. 1958. The climate and vegetation of the Knuckles region of Ceylon. *The Ceylon Forester*, 3(3 & 4): 201-260.

de Silva, Anslem. 1981. Snakebite in Anuradapura District, *The Snake*, 13(2): 117-130.

de Silva, Anslem. 1982. Snakebites and its effects on the snake populations in Sri Lanka, *Proc. IUCN/SSC, Snake Group*, Madras pp. 1.

de Silva, Anslem. 1990. *Colour Guide to the Snakes of Sri Lanka.* R & A Publishing Ltd., Avon, England, 130 pp.

de Silva, Anslem. 2001. *The Herpetofauna of Sri Lanka: historical aspects and current status.* Ministry of Environment, 100 pp

de Silva, Anslem. 2003. *The Biology and status of the star tortoise (Geochelone elegans) in Sri Lanka.* Ministry of Environment, 100 pp.

de Silva, Anslem., A. M. Bauer, S. Goonewardene, J. Drake, S.Nathanael, W.P.R.Chandraratne, and S.A.U.S. Somathilaka. 2005c.Status of the agamids in the knuckles massif with special reference to *Calotes liocephalus* Günther, 1872 and *Cophotis ceylanica* Peters, 1861. *Lyriocephalus* Special issue, Volume 6 Numbers 1 & 2:

de Silva, Anslem., C. C. Austin, A. M. Bauer, S. Goonewardene, J. Drake, T. Shripathy, S. Ramesh, K. Suthagar & A. Kajatheepan. 2005h. Observations on the skinks inhabiting the Knuckles massif: with special reference to genus *Lankascincus. Lyriocephalus* Special issue, Volume 6 Numbers 1 & 2:

de Silva, Anslem., A. M. Bauer, S. Goonewardene, J. Drake, S. Nathaniel & P. de Silva. 2005k. Some observations on the geckos inhabiting the Knuckles massif. *Lyriocephalus* Special issue, Volume 6 Numbers 1 & 2:

de Silva, Anslem., S. Goonewardene, A. Bauer, C. Austin, J. Drake & P. de Silva. 2005n. Notes on the snakes inhabiting the Knuckles massif with special reference to *Uropeltis melanogaster* (Gray, 1858) and *Uropeltis phillipsi* (Nicholls, 1929). *Lyriocephalus* Special issue, Volume 6 Numbers 1 & 2:

de Silva, Anslem., S. Goonewardene, J. Drake, & P. de Silva. 2005o. The amphibian diversity in the Knuckles massif with special reference to the relict species. *Lyriocephalus* Special issue, Volume 6 Numbers 1 & 2:

de Silva, Anslem., K. B. Ranawana & S.Goonewardene. 2005q. Some observations of the mollusks of the Knuckles massif. *Lyriocephalus* Special issue, Volume 6 Numbers 1 & 2:

de Silva, Anslem., R. M. M. Chandraratne, S. Goonewardene, J.A.D.M.M. Jayasuriya, D. Ellepola, H.M.N.W. Herath, P.B.N. Abeywardana & W. M. R. P. K. Chandradasa. 2005r. Evidence of prehistoric cave dwellers inhabiting the Knuckles massif: preliminary archaeological findings. *Lyriocephalus* Special issue, Volume 6 Numbers 1 & 2:

de Silva, P. H. D. H. 1980. *Snake Fauna of Sri Lanka.* National Museums of Sri Lanka. Colombo, xi + 472 pp.

Deraniyagala, P. E. P. 1953. *A Colored atlas of some vertebrates from Ceylon, Vol.2, Tetrapod reptilia.* Ceylon National Museum, 101 pp.

Deraniyagala, P. E. P. 1955. *A Colored Atlas of some Vertebrates from Ceylon. Serpentoid Reptilia.* Ceylon national Museums, Colombo, vii + 107 pp.

Dutta, S. K. & K. Manamendra-Arachchi. 1996. *The Amphibian Fauna of Sri Lanka.* Wildlife Heritage Trust of Sri Lanka, Colombo 1-230.

Gazette. 2000. The Gazette of eh Democratic Socialist Republic of Sri Lanka (Extraordinary). No. 1130/22 of 5th may 2000. 30 pp.

Gans, C. 1973. Uropeltid Snakes - Survivors in a changing World, *Endeavour*, 32(166): 60-65

Gans, C. & Fetcho, J. R. 1982. The Sri Lankan Genus *Aspidura* (Serpentes. Reptilia, Colubridae). *Annals of Carnegie Museum*, 51(14): 271-316.

Ginige, P. 1995. Reptile fauna of the Knuckles Range, Sri Lanka, *Lyriocephalus*. 1(1 & 2): 38–43.

Giragama, W. M. G. B. & C. M. Madduma Bandara. 1993. Rainfall and relative humidity of the Dumbara Hills (Knuckles Range). *Annual Review 1992,* Institute of Fundamental Studies, Kandy, pp.72-73.

Greer, A. E. 1991. Lankascincus a New Genus of Scincid Lizards from Sri Lanka, with Descriptions of Three New Species. *Journal of Herpetology,* 25(1): 59-64.

Gunawardane, H. G. 2003. Ecological implications of cardamom cultivation in the high altitudes of Knuckles Forest Reserve, Central; province, *Sri Lanka. The Sri Lanka Forester.* 26: 1-9.

International Institute for Environment and Development. 1992. *Environmental Synopsis of Sri Lanka.* Overseas Development Administration, 26 pp.

IUCN Sri Lanka & Forest Department. 1994. *Management plan for the conservation of the Knuckles Forest. Phase 2.* Forest Department, Colombo. 58 pp + appendices.

IUCN Sri Lanka 2000. *The 1999 list of threatened fauna and flora of Sri Lanka.* Colombo: IUCN Sri Lanka. 114 pp.

Kankanamge, A. D. H. K. & H. M. Gunatilake. 1993. Factors influencing the dependency of peripheral communities of Knuckles on forest resources. *Proceedings of the 49th Annual Sessions. Sri Lanka Association for the Advancement of Science.* Section B: 70 -71.

Knox, R. 1681. *An historical relation of the island of Ceylon in the East Indies.* Richard Chiswell, London, 189 pp.

Manamendra-Arachchi, K. & R. Pethiyagoda. 2005. The Sri Lankan shrub-frog of the genus *Philauts* Gistel, 1848 (Ranidae: Rhacophorinae), with description of 27 new species. *The Raffles Bulletin of Zoology*. Supplement 12.: 163-303.

Meegaskumbura, M. & K. Manamendra-Arachchi 2005. Description of eight new species of shrub-frogs (Ranidae: Rhacophorinae: *Philautus*) from Sri Lanka. *The Raffles Bulletin of Zoology*. Supplement 12.: 305- 338. .

Nanayakkara, V. R. 1988. Conservation of the Knuckles range of forests. *Preliminary workshop for the preparation of a conservation plan for the Knuckles range of forests.* Kandy. 8 pp.

Navaratne, W. M. & C.M. Madduma Bandara. 1993. Cardamom cultivation in the Dumbara Hills (Knuckles Range) and its environmental impact. *Annual Review* 1992. Institute of Fundamental Studies, Kandy. pp. 73-74.

Navaratne, W. M. & C.M. Madduma Bandara.. 1995. Categorization and analysis of plant and soil in two types of forest in the Dumbara Hills (Knuckles

Range). *Annual Review* 1994. Institute of Fundamental Studies, Kandy. pp. 81-81.

Peiris, R. 1988. Some thoughts on the Knuckles. *Ceylon Daily News*. September.

Pethiyagoda, R. & K. Manamendra-Arachchi. 1998. A revision of the endemic Sri Lankan agamid lizard genus *Ceratophora* Gray, 1835, with description of two new species. *J. South Asian Nat. Hist.*, 3(1): 1-50.

Ratnayake, H. D. 2005. Some aspects of the vegetation of the Knuckles ecosystem. *The Diversity of the Dumbara Mountains (The Knuckles Massif, Sri Lanka): with special reference to its herpetofauna. Lyriocephalus* Special issue, Volume 6 Numbers 1 & 2

Senanayake, F. R., M. Soule & J. W. Senner. 1977. Habitat values and endemicity in the vanishing rain forests of Sri Lanka. *Nature, London,* 265: 351-354.

Skeen, W. 1868. *The Knuckles and other poems*. W. L. H. Skeen & Co, 41 Chatham Street, Colombo. 181 pp.

Sri Bharathie, K. P. 1979. Man and Biosphere reserves in Sri Lanka. *Sri Lanka Forester*. 14 (1 & 2): 37-40.

Smith, M. A. 1931. *The fauna of British India, including Ceylon and Burma. Reptilia & Amphibia. Vol. 11- Sauria.* Taylor & Francis, London. 440 pp. Reprinted by Today & Tomorrow Printers & Publishers, New Delhi, 1974 and 1995.

Smith, M. A. 1935. *The fauna of British India, including Ceylon and Burma. Reptilia & Amphibia. Vol. 11- Sauria*. Taylor & Francis, London. 440 pp.

Smith, M. A. 1943. *The Fauna of British India, Ceylon and Burma, including the Whole of the Indo-Chinese Sub-Region. Reptilia and Amphibia Vol. 3 - Serpents* (R.B.S. Sewell editor) Taylor and Francis, London, xii + 568 pp.

Sri Barathi K. P. 1979. Man and Biosphere reserves in Sri Lanka. *Sri Lanka Forester*. 14 (1 & 2): 37-40.

Stuart, S., J. S. Chanson, N.A. Cox, B.E. Young, A.S.L. Rodrigues, D.L. Fischman & R.W. Waller, 2004. Status and trends of amphibian declines and extinctions worldwide. Science, 306: 1783-1786.

Taylor, E. H. 1950. Ceylonese lizards of the family scincidae. *Uni. Kansas Sci.Bull.* 33(13): 481-518.

Taylor, E. H. 1953. A brief review of Ceylonese snakes *University Kansas Sci. Bull.* 33 (14): 519-603.

Table 1
Amphibian species observed during the present study and by other authorities

Amphibian species	IUCN & Forest Dept. 1994	Rathnayake 2001	Bambaradeniya & Ekanayake, 2003	Present Study 2004 & 2005
Adenomus kelaartii	Not	Observed	Observed	Observed
Bufo melanostictus	Observed	Observed	Observed	Observed
Kaloula taprobanica	Observed	Not	Observed	Observed
Microhyla ornatus	Observed	Observed	Observed	Observed
Microhyla zeylanica	Not	Not	Observed	Not
Ramanella obscura	Observed	Observed	Observed	Observed
Ramanella variegate	Not	Not	Not	Observed
Euphlyctis cyanophlyctis	Observed	Observed	Observed	Observed
Lankanectes corrugatus	Observed	Observed	Observed	Observed
Fejervarya kirtisinghei	Observed	Observed	Observed	Observed
Fejervarya limnocharis	Observed	Observed	Observed	Observed
Nannophrys marmorata	Observed	Observed	Observed	Observed
Rana gracilis	Observed	Not	Observed	Observed
Rana temporalis	Not	Observed	Observed	Observed
Sphaeroteca breviceps	Not	Not	Not	Observed
Sphaeroteca rolandae	Not	Not	Not	Observed
Philautus cavirostris	Not	Not	Not	Observed
P. femoralis	Not	Observed	Not	Observed
Philautus fergusonianus	Not	Observed	Observed	Observed
Philautus fulvus	Described in 2005	Described in 2005	Described in 2005	Observed
Philautus macropus	Not	Observed		Observed
Philautus microtympanum	Not	Observed		Observed
Philautus steineri	Described in 2005	Described in 2005	Described in 2005	Observed
Philautus microtympanum	Not	Observed	Observed	Observed
Philautus reticulatus	Not	Observed	Not	Observed
Philautus stictomerus	Not	Not	Not	Observed
Philautus stuarti	Described in 2005	Described in 2005	Described in 2005	Observed
Unidentified *Philautus sp.* A	Not	Not	Not	Observed
Unidentified *Philautus sp.* B	Not	Not	Not	Observed
Unidentified *Philautus sp.* C	Not	Not	Not	Observed
Polypedates cruciger	Not	Not	Observed	Observed
Polypedates eques	Not	Observed	Not	Observed
Polypedates maculatus	Not	Not	Not	Observed
Theloderma schmarda	Observed	Observed	Not	Not
Ichthyophis glutinosus	Not	Not	Not	Observed

Table 2
Snake species observed during the present study and by other authorities

Snake species	IUCN & Forest Dept. 1994	Ginige, 1994	Rathnayake *et al*, 1999	Bambaradeniya & Ekanayake, 2003	Present Study 2004 & 2005
Python molurus	Observed	Observed	Not	Observed	Observed
Cylindrophis maculatus	Not	Not	Not	Not	Observed
Ahaetulla nasuta	Observed	Observed	Observed	Observed	Observed
Ahaetulla pulverulenta	Not	Not	Not	Observed	Not
Amphiesma stolatum	Not	Not	Not	Not	Observed
Aspidura brachyorrhos	Not	Not	Not	Not	Observed
Aspidura trachyprocta	Observed	Observed	Not	Not	Not
Atretium schistosum	Not	Not	Not	Not	Not
Balanophis ceylonensis	Observed	Observed	Not	Not	Not
Boiga barnesii	Not	Not	Not	Observed	Not
Boiga ceylonensis	Observed	Observed	Not	Observed	Observed
Boiga forsteni	Not	Not	Not	Observed	Not
Boiga trigonatus	Not	Not	Not	Observed	Observed
Chrysopelea ornata	Not	Not	Not	Observed	Observed
Chrysopelea taprobanica	Not	Not	Not	Observed	Not
Coeloganthus helena	Not	Not	Not	Observed	Observed
Dendrelaphis bifernalis	Observed	Observed	Observed	Observed	Observed
D. caudolineolatus				Observed	Observed
Dendrelaphis tristis	Observed	Observed	Not	Not	Observed
Dryocalamus nympha	Not	Not	Not	Not	Observed
Haplocercus ceylonensis	Not	Not	Not	Not	Observed
Lycodon aulicus	Observed	Not	Not	Not	Observed
Lycodon osmanhilli	Observed	Not	Not	Not	Not
Lycodon striatus	Not	Not	Not	Not	Observed
Liopeltis calamaria	Not	Not	Not	Not	Observed
M. plumbicolor	Observed	Observed	Observed	Observed	Observed
Oligodon sublineatus	Observed	Observed	Not	Observed	Observed
Oligodon taneolatus	Observed	Observed	Not	Observed	Not
Ptyas mucosa maximus	Observed	Observed	Observed	Observed	Observed
Xenochrophis asperrimus	Observed	Observed	Not	Not	Observed
Xenochrophis piscator	Observed	Observed	Observed	Observed	Observed
Bungarus caeruleus	Observed	Observed	Not	Observed	Observed
Bungarus ceylonicus	Observed	Observed	Not	Not	Observed
Naja naja	Not	Not	Not	Observed	Observed
R. braminus	Not	Not	Not	Observed	Observed
Typhlops leucomelas	Not	Not	Not	Not	Observed
Pseudotyphlops phillipinus	Not	Not	Not	Observed	Not
Rhinophis blythi	Observed	Observed	Not	Observed	Not
Rhinophis philippinus	Not	Not	Not	Not	Observed
Rhinophis trevelyana	Not	Not	Not	Observed	Not
Uropeltis melanogaster	Not	Not	Not	Not	Observed
Uropeltis phillipsi	Not	Not	Not	Not	Observed
Daboia russelii	Observed	Observed	Not	Observed	Observed
Hypnale hypnale	Observed	Observed	Not	Observed	Observed
Hypnale neap	Not	Not	Observed	Not	Observed
T. trigonocephalus	Observed	Observed	Observed	Observed	Observed

Table 3
Lizard and chelonian species observed during the present study and by other authorities

Species	IUCN & Forest Dept. 1994	Ginige, 1994	Rathnayake *et al*, 1999	Bambaradeniya & Ekanayake, 2003	Present Study 2004 & 2005
Melanochelys t. thermalis	Observed	Observed	Not	Observed	Observed
Geochelone elegans	Not	Not	Not	Not	Observed
Lissemys punctata	Observed	Observed	Observed	Observed	Observed
Calotes calotes	Observed	Observed	Observed	Observed	Observed
C. ceylonensis	Observed	Observed	Not	Not	Observed
C. liocephalus	Observed	Observed	Observed	Observed	Observed
C. liolepis	Observed	Observed	Observed	Observed	Observed
C. versicolor	Observed	Observed	Observed	Observed	Observed
Ceratophora tennentii	Observed	Observed	Observed	Observed	Observed
Cophotis ceylanica	Not	Not	Not	Observed	Observed
Lyriocephalus scutatus	Observed	Observed	Not	Observed	Observed
Otocryptis wiegmanni	Observed	Observed	Not	Observed	Observed
Otocryptis nigristigma	Described in 2005	Described in 2005	Described in 2005	Described in 2005	Observed
Cnemaspis scalpensis	Not	Not	Not	Not	Observed
C. kandiana	Observed	Observed	Not	Observed	Observed
C. podihuna	Not	Not	Not	Observed	Observed
C. tropidogaster	Not	Not	Not	Not	Observed
Cyrtodactylus soba	Observed	Observed	Observed	Observed	Observed
Geckoella triedrus	Not	Not	Not	Observed	Observed
Gehyra mutilata	Observed	Observed	Not	Observed	Observed
Hemidactylus brooki parvimaculatus	Not	Not	Not	Not	Observed
H. depressus	Not	Not	Not	Observed	Observed
H. frenatus	Not	Not	Observed	Observed	Observed
H. leschenaultii	Observed	Observed	Not	Observed	Observed
H. triedrus lankae	Not	Not	Not	Not	Observed
Hemiphyllodactylus typus	Observed	Observed	Not	Not	Not
Chalcidoseps thwaitesii	Observed	Observed	Not	Observed	Observed
Dasia halianus	Not	Not	Not	Not	Observed
Lankascincus deraniyagalae	Not	Not	Not	Not	Observed
L. fallax	Observed	Observed	Observed	Observed	Observed
L. gansi	Not	Not	Not	Not	Observed
L. taprobanensis	Not	Not	Not	Not	Observed
L. taylori	Not	Not	Not	Not	Observed
Lygosoma punctatus	Not	Not	Not	Not	Observed
Mabuya carinata	Observed	Observed	Not	Observed	Observed
Mabuya macularius	Observed	Observed	Not	Observed	Observed
Nessia bipes	Not	Not	Not	Not	Observed
N. monodactylus	Not	Not	Not	Observed	Not
N. sarasinorum	Not	Not	Not	Not	Observed
Varanus bengalensis	Observed	Observed	Observed	Observed	Observed
Varanus salvator	Observed	Observed	Observed	Observed	Observed

Annexure 1

Birds observed in the Knuckles range: Knuckles Expedition 2004

No.	Species	Common name	Locality
1	*Tachybaptus ruficollis capensis*	Little grebe	Hettipola (Lakegala side)
2	*Phalacrocorax niger*	Little cormorant	Hettipola (Lakegala side)
3	*Phalacrocorax carbo sinensis*	great cormorant	Hettipola (Lakegala side)
4	*Anhinga melanogaster*	Indian darter	Hettipola (Lakegala side)
5	*Ardeola grayii grayii*	Indian pond heron	Hettipola (Lakegala side)
6	*Bubulcus ibis coromandus*	cattle egret	Hettipola (Lakegala side)
7	*Egretta garzetta garzetta*	Little egret	Hettipola (Lakegala side)
8	*Egretta intermedia intermedia*	median egret	Hettipola (Lakegala side)
9	*Egretta alba modesta*	large egret	Hettipola (Lakegala side)
10	*Ardea cinerea cinerea*	grey heron	Hettipola (Lakegala side)
11	*Threskiornis melanocephalus*	white ibis	Hettipola (Lakegala side)
12	*Milvus migrans govinda*	black kite	Hettipola (Lakegala side)
13	*Haliastur indus Indus*	Brahmin kite	Hettipola (Lakegala side)
14	*Ictinaetus malayensis perniger*	black eagle	Kobonila
15		quail sp.	Hettipola (Lakegala side)
16	*Galloperdix bicalcarata*	Ceylon spur fowl	Hettipola (Lakegala side)
17	*Gallus lafayetti*	Ceylon jungle fowl	Hettipola (Lakegala side)
18	*Amauromis phoenicurus phoenicurus*	white breasted waterhen	Hettipola (Lakegala side)
19	*Gallinula chloropus indica*	common moorhen	Hettipola (Lakegala side)
20	*Hoplopterus indicus lankae*	Red wattled lapwing	Hettipola (Lakegala side)
21	*Treron pompadura pompadura*	pompadour green pigeon	Hettipola (Lakegala side)
22	*Streptopelia chinensis ceylonensis*	spotted dove	Kobonila
23	*Columba torringtonii*	Ceylon wood pigeon	Riverstone
24	*Chalcophaps indica robinsoni*	emerald dove	Hettipola (Lakegala side)
25	*Psittacula calthropae*	Lanyard's parakeet	Widely distributed
26	*Cuculus microptuers micropterus*	Indian cuckoo	
27	*Centropus sinensis parroti*	common coucal	Widely distributed
28	*Otus bakkamoena bakkamoena*	collared scoops owl	Kobonila
29	*Collocalia unicolor*	Indian edible nest swift	Kobonila
30	*Apus affinis singalensis*	house swift	Kobonila
31	*Halcyon smyrnensis fusca*	white breasted kingfisher	Hettipola (Lakegala side)
32	*Alcedo atthis taprobana*	common kingfisher	Mimure
33	*Ceryle rudis leucomelanura*	pied kingfisher	Hettipola (Lakegala side)
34	*Merops orientalis orientalis*	Little green bee eater	Hettipola (Lakegala side)
35	*Ocyceros gingalensis*	Ceylon grey hornbill	Hettipola (Lakegala side)
36	*Anthracoceros coronatus*	Malabar pied hornbill	Hettipola (Lakegala side)
37	*Megalaima flavifrons*	yellow fronted barbet	Kobonila
38	*Megalaima rubricapilla*	Ceylon small barbet	Kobonila
39	*Megalaima zeylanica zeylanica*	brown headed barbet	Hettipola (Lakegala side)
40	*Picus xanthopygaeus*	small scaly headed woodpecker	Kobonila
41	*Anthus rufulus malayensis*	Indian pipit	Kobonila
42	*Pericrocotus flammeus flammeus*	orange minivet	Hunnasgiriya area
43	*Hemipus picatus leggei*	pied flycatcher shrike	Kobonila
44	*Pycnonotus cafer haemorrhousus*	Red vented bulbul	Widely distributed
45	*Pycnonotus penicilatus*	yellow eared bulbul	Riverstone
46	*Iole indica indica*	yellow browed bulbul	Riverstone
47	*Hypsipetes leucocephalus humii*	black bulbul	Widely distributed
48	*Aegithinia tiphia multicolor*	common iora	Riverstone
49	*Copsychus saularis ceylonensis*	magpie robin	Hunnasgiriya area

50	*Saxicola caprata atrata*	pied bush chat	Hunnasgiriya area
51	*Saxicoloides fulicata leucoptera*	black robin	Hunnasgiriya area
52	*Pomatorhinus horsfieldii holdsworthi*	Indian scimitar babbler	Riverstone
53	*Prinia socialis brevicauda*	ashy prinia	Hettipola (Lakegala side)
54	*Zoothera dauma imbricata*	scaly thrush	Riverstone
55	*Prinia inornata insularis*	Ceylon white browed prinia	Hettipola (Lakegala side)
56	*Orthotomus sutorius sutorius*	common tailor bird	Hettipola (Lakegala side)
57	*Culicicapa ceylonensis ceylonensis*	grey headed flycatcher	Kandegama
58	*Bradypterus palliseri*	Ceylon warbler?	Riverstone
59	*Eumyiasis sordida*	dusky blue flycatcher	Kobonila
60	*Rhipidura aureola compressirostris*	white browed fantail flycatcher	Hettipola (Lakegala side)
61	*Terpsiphone paradisi paradise*	paradise flycatcher	Widely distributed
62	*Rhopocichla atriceps nigrifrons*	black fronted babbler	Kobonila
63	*Turdoides affinis taprobanus*	southern common babbler	Widely distributed
64	*Parus major mahrattarum*	grey tit	Hettipola (Lakegala side)
65	*Nectarinia zeylonica zeylonica*	purple rumped sunbird	Hettipola (Lakegala side)
66	*Zosterops palpebrosa egregia*	small white eye?	
67	*Zosterops ceylonensis*	Ceylon hill white eye?	Kobonila
68	*Oriolus xanthornus ceylonensis*	black headed oriole	Hettipola (Lakegala side)
69	*Dicrurus macrocercus*	black drongo	Hettipola (Lakegala side)
70	*Dicrurus paradiseus ceylonicus*	racquet tailed drongo	Widely distributed
71	*Corvus macrorhyncos culminates*	jungle crow	Niter cave
72	*Acridotheres tristis melanosternus*	common mynah	Widely distributed
73	*Gracula ptilogenys*	Ceylon hill mynah ??	Kobonila
74	*Gracula religiosa indica*	common hill mynah ??	
75	*Passer domesticus indicus*	house sparrow	Hettipola (Lakegala side)
76	*Hirundo daurica nipalensis*	Red rumped (Ceylon) swallow	Kobonila
77	*Hirundo tahahitica domicola*	hill swallow	Kobonila
78	*Lonchura malacca Malacca*	black headed munia	Hettipola (Lakegala side)
79	*Batrachostomus moniliger*	Sri Lanka Frogmouth	Kalupahana trail
80	*Catrimulgus atritennis*	Jerdon's nightjar	Illukkumbura road
81	*Turdoides rufescens*	Ceylon rufous babbler	Mimure

Source: Knuckles Expedition 2004 & 2005

Annexure 2

Mammals observed in the Knuckles range: Knuckles Expedition 2004

Species	Common Name
Axis (axis) axis ceylonensis	Spotted Deer
Bubalus bubalis bubalis	Buffalo
Cervus unicolour unicolour	Sri Lanka sambhur
Elephas maximus maximus	Sri Lanka Elephant
Felis chaus kelaarti	Sri Lanka jungle cat
Funambulus palmarum	Sri Lanka palm-squirrel
Herpestes smithii zeylanicus	Sri Lanka ruddy mongoose
Herpestes vitticollis vitticollis	striped-necked mongoose
Kalu-vandhura	Bear monkey
Macaca sinica	Toque monkey
Manis crassicaidata	Pangolin
Paradoxurus hermaphroditus	Common Indian palm-cat
Paradoxurus zeylonensis	Golden palm-cat
Petaurista petaurista lanka	Flying Squirrel
Pteropus giganteus giganteus	Common Flying fox
Ratufa macroura	Sri Lanka giant squirrel
Ratus ratus kandianus	common Sri Lanka house rat
Semnopithecus priam thersites	Ceylon Grey Langur
Suncus spps	Shrew
Sus scrofa cristatus	Wild Boar
Tatera indica ceylonica	Antilope-Rat
Tragulus meminna	
Viverricula indica mayori	

Source: Knuckles Expedition 2004 & 2005

Annexure 3

Snails observed in the Knuckles range: Knuckles Expedition 2004

Species	Status
Cligospira polei	Endemic
Corilla erronea	Endemic
Euplecta semidecussata	
Cryptozona chenui	Endemic
Euplecta travancorica	
Beddomea albizonatus	Endemic
Theobaldios bairdi	Endemic
Cryptozona chenui	Endemic
Cyclophorus sp:	
Euplecta sp:	
Glessula sinhila	Endemic
Ratnadvipia irradians	Endemic Genus
Actina fulica	Introduced sp:
Oligospira polei	Endemic
Crytozona bristralis	
Aulophoma grande	Endemic
Beddomea trifasciatus	Endemic
Euplecta colletti	Endemic
Teobaldius annulatus	Endemic
Beddomea albizonaus	Endemic
Aulopoma grande	Endemic (Endemic Genus)
Beddomea alibizonatus	Endemic
Euplecta colleti	Endemic
Euplecta semidecusata	
Corilla erronea	Endemic
Euplecta layardi	Endemic
Oligospira polei	Endemic
Subilina octana	
Philalanaka sp	
Corilla gudei	Endemic

Source: de Silva & Ranawana, 2005

Annexure 4

Cardamom (*Elettaria cardamomum*) locally known as the 'Queen of the species' has a history of over several centuries in the country. The Dutch traded in it, and it has since been an important export item of the country, on a large scale at least from 1806 but recorded in literature as early as Pliny's time (Lewis, 1934). However, the large scale commercial cultivation of cardamom which can be observed today commenced in the late 1960's. The total area of cardamom cultivation in the Knuckles is been recorded as 2,745 ha. This is considered to constitute 55 percent of the total cardamom cultivation area in Sri Lanka (IUCN & Forest, 1994).

Three negative aspects of cardamom cultivation in the Knuckles are:

1. Opening of the canopy and clearing of the under-story simplifies the forest's structure and reduces the number of endemic plant species. This will increase the runoff rate of rain water, increase soil erosion and facilitate the encroachment of alien invasive plant species.
2. Increase threats to the endemic fauna. Abeygunawardena & Vincent (1993) consider that the number of species inhabiting the Knuckles is yet unknown and that there is a distinct possibility of some of these species becoming extinct.
3. Cardamom cultivators use fuel wood harvested from the forest for curing the cardamom capsules.

The cultivation of cardamom in the Knuckles conservation area has been banned by the Forest Department. The implementation of legislation demanding that cultivation be abandoned in the conservation forest is currently underway.

Annexure 5

Summary statistics of lizard (*Lankascincus, Calotes, Cyrtodactylus* and *Geckoella*) and snake (*Boiga* and *Uropeltis,*) body temperatures found in the Knuckles forest. Statistics shown are mean body temperatures (T_b) with standard deviations (Std. Dev.), ranges, samples sizes of body temperatures *N* and associated air and substrate temperature means. The values of P_1 and P_2 indicate probabilities of differences between body temperatures and associated air (T_{am}) and substrate temperatures (T_{sm}) using two sample *t*-tests with variances assumed unequal.

Species	*Mean* T_b	*Std. Dev*	*Range*	N	T_{am}	P_1	*d.f.*	T_{sm}	P_2	*d.f*
Lankascincus	23.5	2.6	19.7– 27.4	10	21.9	0.15	16	21.8	0.49	1
Calotes	25.6	4.4	20.6– 30.7	9	24.1	0.39	12	24.9	0.82	7
Cyrtodactylus	24.1	4.3	17.9– 32.7	12	22.4	0.31	18	24.4	0.31	18
Geckoella	22.9	1.2	22.3– 24.3	3	25.5	.08	3	-	-	-
Boiga	23.0	1.5	21.9- 24.7	3	25.7	0.52	2	21.3	0.36	3
Uropeltis	23.1	1.6	20.8-24.7	4	24.9	0.18	25.7	0.69		1

Annexure 4

Cardamom (*Elettaria cardamomum*) locally known as the 'Queen of the species' has a history of over several centuries in the country. The Dutch traded in it, and it has since been an important export item of the country, on a large scale at least from 1806 but recorded in literature as early as Pliny's time (Lewis, 1934). However, the large scale commercial cultivation of cardamom which can be observed today commenced in the late 1960's. The total area of cardamom cultivation in the Knuckles is been recorded as 2,745 ha. This is considered to constitute 55 percent of the total cardamom cultivation area in Sri Lanka (IUCN & Forest, 1994).

Three negative aspects of cardamom cultivation in the Knuckles are:

1. Opening of the canopy and clearing of the under-story simplifies the forest's structure and reduces the number of endemic plant species. This will increase the runoff rate of rain water, increase soil erosion and facilitate the encroachment of alien invasive plant species.
2. Increase threats to the endemic fauna. Abeygunawardena & Vincent (1993) consider that the number of species inhabiting the Knuckles is yet unknown and that there is a distinct possibility of some of these species becoming extinct.
3. Cardamom cultivators use fuel wood harvested from the forest for curing the cardamom capsules.

The cultivation of cardamom in the Knuckles conservation area has been banned by the Forest Department. The implementation of legislation demanding that cultivation be abandoned in the conservation forest is currently underway.

Annexure 5

Summary statistics of lizard (*Lankascincus, Calotes, Cyrtodactylus* and *Geckoella*) and snake (*Boiga* and *Uropeltis,*) body temperatures found in the Knuckles forest. Statistics shown are mean body temperatures (T_b) with standard deviations (Std. Dev.), ranges, samples sizes of body temperatures *N* and associated air and substrate temperature means. The values of P_1 and P_2 indicate probabilities of differences between body temperatures and associated air (T_{am}) and substrate temperatures (T_{sm}) using two sample *t*-tests with variances assumed unequal.

Species	*Mean* T_b	*Std. Dev*	*Range*	N	T_{am}	P_1	*d.f.*	T_{sm}	P_2	*d.f*
Lankascincus	23.5	2.6	19.7– 27.4	10	21.9	0.15	16	21.8	0.49	1
Calotes	25.6	4.4	20.6– 30.7	9	24.1	0.39	12	24.9	0.82	7
Cyrtodactylus	24.1	4.3	17.9– 32.7	12	22.4	0.31	18	24.4	0.31	18
Geckoella	22.9	1.2	22.3– 24.3	3	25.5	.08	3	-	-	-
Boiga	23.0	1.5	21.9- 24.7	3	25.7	0.52	2	21.3	0.36	3
Uropeltis	23.1	1.6	20.8-24.7	4	24.9	0.18	25.7	0.69		1

Plate 1

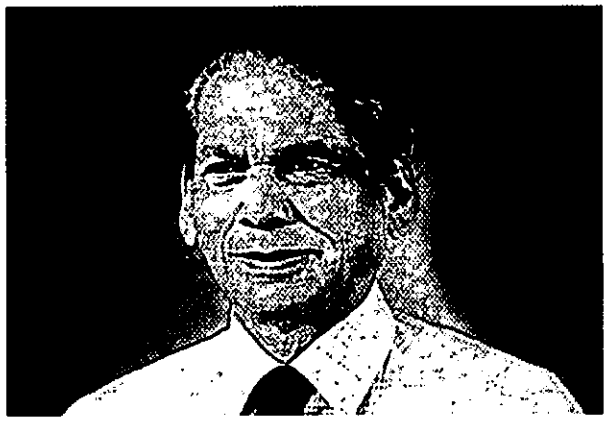


Figure 1. P. G. Cooray

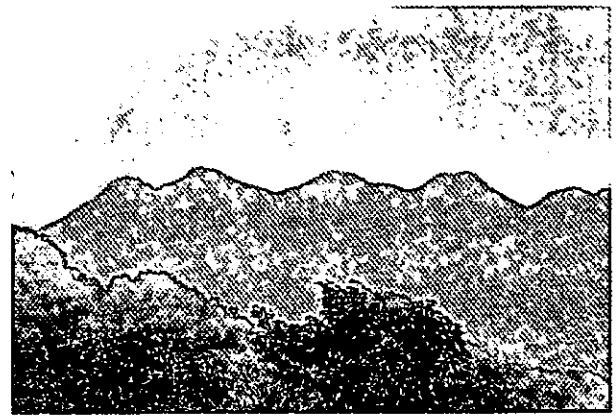


Figure 2. The Knuckles mountains

Figure 3. General John Fraser

Figure 4. Elsie Cook

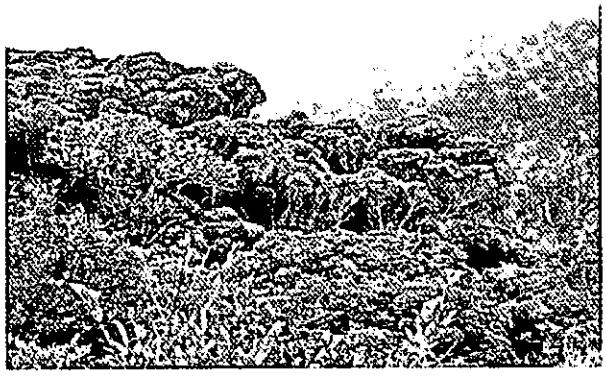


Figure 5. Montane forest

Figure 6. Riverine forest

Figure 7. Cardamom plantation

Figure 8. Soil erosion

Photographs: © Suraj Goonewardene and Anslem de Silva

The Diversity of the Dumbara Mountains (The Knuckles Massif, Sri Lanka): With special reference to its herpetofauna.
Lyriocephalus Special issue, 2005 November, Volume 6 Numbers 1 & 2: 37-42
ISSN 1391-0833

SPECIES DIVERSITY AND RICHNESS OF THE HERPETOFAUNA IN LARGE LEAF LITTER PLOTS IN THE KNUCKLES ECOSYSTEM

Anslem de Silva[1], S. Goonewardene[2], J. Drake[2], P. de Silva[1], R.D.C.S.K.Dasanayaka[3], A. M. R. K. Amarakoon[3] & M. M. Goonasekera[3]

[1]15/1 Dolosbage road, Gampola, Sri Lanka. Email: kalds@sltnet.lk
[2]97, Battersea Park Road, London, SW9 4DU, UK. E-mail: hsr.wild@gmail.com (University of Edinburgh, UK)
[2]Creagard, Isle of Mull, PA75 6RA, UK. E-mail: jfdrake@gmail.com (University of Edinburgh, UK)
[3]Dept of Biological Sciences, Rajarata University of Sri Lanka

Keywords: quadrat studies, reptiles, amphibians, species diversity, Knuckles,

Introduction

The first report of forest floor leaf litter plot studies of the herpetofauna were conducted by Das and de Silva (1998) and for amphibians by Karunaratne (1998). Subsequently, several plot studies were conducted in the country (de Silva, 2001, Pradeep, 2004, Herath *et al* 2001, Weerakoon, 2001; Nathanael *et al* 2004 and others). All these authors used the widely used 8 x 8 m leaf litter plot technique as described by Allmon (1991) and Jaeger & Inger (1994) or a modification of the plot size. Different authors in the world (Rocha et al, 2001) used several modifications of the size of the quadrat. These, ranged considerably in the size from 1 x 1m; 1 x 2 m; 5 x 5 m; 6 x 6 m; 8 x 8 m to large plots of 10 x 10 or 20 x 20 m plots.

The Knuckles ecosystem is comprised of several distinct vegetation habitats, such as montane and sub-montane rain forests, elfin forests, monsoon forests, grasslands, riverine forests, plantations and etc. Hence, during the Knuckles expedition from June to August 2004, forty large leaf litter quadrats measuring 20 x 20 m were conducted in these vegetation habitats to investigate for the herpetofauna inhabiting in these vegetation habitats.

Methodology

Study period

June to August 2004.

Study area

Knuckles ecosystem

Field methods

1. The survey was conducted in the following vegetation habitats: Upper montane rain forests, elfin forests, riverine forests, monsoon forests, fragmented forests and plantations (cardamom, pine and acacia).
2. A cluster of 2 or 3 plots spaced approximately 100 m apart was investigated in each of the following major vegetation habitats: Upper Montane cloud forests; Elfin or Pigmy forest; Monsoon forests; Riverine forests; Fragmented forests and plantations.
3. Large quadrates (20m x 20m) for sampling forest floor litter was adopted in the present study. In addition, all large trees inside the quadrat was checked by climbing for any arboreal reptiles and amphibians.
4. Six persons, usually on their hands and knees, removed the leaf-litter and turned over logs and boulders. Approximately 3-4 cm of the soil was checked for fossorial amphibians, reptiles and their eggs, using standard gardening tools. One observer kept an overall check for any animals attempting to escape.
5. One person kept on recording all findings and details of the plot in a structured survey form.

6. GPS location, altitude, environmental data within the quadrate such as the

7. relative humidity 1.5 m above the ground inside the quadrate were recorded, the latter using a Hair-Hygrometer (Gischer - Germany). Air temperature (one and half meters above the ground), and soil temperature (five cm inside soil) digital thermometer (infra-red Pyrometer)(130 mm stainless steel sensor probe model ST-9263A/B/C),

8. The soil hardness of the microhabitat was measured using a penetrometer (pocket penetrometer model-STCL-3).

9. Botanical specimens obtained were identified at the Herbarium, Royal Botanical Gardens, Peradeniya and manuals Ashton *et al* (1997) and Gunatilleke (1996).

10. Amphibians and reptiles within the quadrats were identified using manuals by Deraniyagala (1953), de Silva (1990), Dutta and Manamendra-Arachchi (1996), Manamendra-Arachchi & Pethiyagoda (2005), Meegaskumbura & Manamendra-Arachchi (2005) and Greer (1991).

11. Animals were sexed, measurements taken in millimeters using a micromatic 1m steel tape.

12. Stomach contents from random specimens were obtained for analysis by using an intragastric cannula. The distilled water was gently squirted into the stomach, while the mouth of the animal was held downwards, thereby flushing the stomach contents, which were collected into sterile bottles. The stomach contents were preserved in 10% formaldehyde and examined in the laboratory under a dissecting microscope.

13. Faecal samples were of some specimens were collected into sterile bottles containing 2 ml of 20% formaldehyde solution. These were examined in the laboratory for parasites.

14. Most specimens and habitats were photographed using Olympus OM 30 cameras using macro and close-up lenses. Fuji Chrome and Fuji Colour, 200 and 100 ASA, 36 exposure films were used.

15. Statistical analysis: data were analysed using Shannon – Weiner diversity index and SAS.

Results

The results from the plot-wise inventory data of amphibians and reptiles are given in Table 1 and detailed data of the 40 quadrates are given Annex 1.

Species diversity. A preliminary survey of between habitat reptile and amphibian species diversity was made using the Shannon – Weiner diversity index. The index is derived from the formula:

$$H = \sum P_i \cdot \log_e(P_i)$$

where the Shannon- Weiner index H is derived from the frequency rating P_i (i.e. from n/N, where n is the single species abundance and N the total abundance) and the natural logarithm of the frequency rating $\log_e(P_i)$. Index values for normal communities usually fall between around 1 and 6, with the higher the index rating the greater the diversity. However the restricted species survey in this work, which was confined to reptiles and amphibians, reduces the potential values. Table 3 shows the index values for the habitats sampled. The highest were from Riverine habitat and Fragmented and acacia forest with Cardamon and cloud forest also with relatively high values. The lowest was from Monsoon forest. Analysis of Variance was used to compare the means and showed that the differences were not significant $F_{(6, 32)} = 0.89, p = 0.51$.

Table 1

Statistical summary of Shannon-Weiner index values. The means are given with their standard deviations (±), ranges and sample sizes (n) - the latter representing the number of habitats surveyed.

Habitat	Plot Number	Mean	± Standard Deviation	Range
Pine plantation	8	0.75	0.26	0.39 – 1.02
Cardamom plantation	6	0.97	0.63	0.00 – 1.67
Monsoon forest	5	0.59	0.40	0.36 – 0.64
Cloud forest	6	0.90	0.33	0.51 – 1.42
Fragmented forest	2	1.00	0.43	0.69 – 1.31
Riverine forest	7	1.01	0.40	0.63 – 1.56
Acacia plantation	4	1.04	0.32	0.69 – 1.46

Discussion

Knuckles ecosystem contains wet, dry and intermediate climatic zones as well as several forest communities. It is also considered as one of the 15 floristic regions of Sri Lanka recognized by Ashton & Gunetilleke (1987). For further details on the vegetation communities refer Rathnayake (2005, in this volume).

Some workers consider the upper montane rain forests, elfin forest and the dieback areas in forests to belong to a single community. However, the plot studies conducted separately at Horton Plains Ecosystem indicated that there is a higher species richness (SR) and species diversity (SD) of the herpetofauna and insect fauna in the forest dieback plots when compared to other habitats investigated (de Silva, 2001). Inger (1980a) found greater SR in logged forests and in plantations than in rainforests, and suggested possible environmental factors, (i.e. abundance of weed species) to be the cause for this difference. Similarly, Heinen (1992) found a higher abundance and species richness (SR) in the more disturbed sites in Costa Rica, but species diversity was greater in less recently disturbed areas. Bickford (1994) too showed that in 8 x 8 m leaf-litter plots the herpetofauna of a montane wet forest at an altitude of 2450-2800 m in Costa Rica was less diverse and abundant than at lower elevations. Bickford (1994) has also observed dominance of a single species. We too observed during the present Knuckles survey that of the reptiles *Lankascincus* species and *Cyrtodactylus soba* were the dominant species found in all habitats.

The forests possess microhabitats that offer the amphibians and reptiles at Knuckles ecosystem a rich and a diverse refugea and microhabitats, such as decaying fallen logs, leaf-litter, crevices and holes in tree trunks and roots, rocks and rubble. These rubble heaps and decaying logs presently act as a refugea for several species of skinks (*Lankascincus, Nessia, Chalcidoseps, Mabuya, Lygosoma)*, Geckos (*Geckoella*), snakes (*Aspidura, Haplocercus, Typhlops* and *Uropeltids*) and amphibians (*Adenomus, Philatus, Ramnella*,etc).

However, at Knuckles we observed several species of the cloud forest agamids as opposed to the monoculture of the pines and acacia. As our plot samples in the six habitats studied were small (av. 3 plots in each habitat), it limited detailed statistical analysis. However, some general impressions can be arrived at by analyzing this data (Table 2).

Earlier studies showed the dominance of frogs over lizards in plot studies conducted in Sri Lanka (Das & de Silva, 1998, de Silva, 2001) and in rain forests in Borneo (Inger, 1980a). The low SR and SD values in primary forests are probably due to the natural rarity of amphibian and reptile species, as reported in other studies from sites in tropical Asia (Das, 1995, 1996: Das & de Silva, 1998; Inger, 1980a, 1980b; Bickford, 1994).

We observed during the survey four fairly distinct patterns of habitat preference and distribution of reptiles and amphibians at Knuckles Massif.

Acknowledgements
We wish to thank: Mr. Sarath Fernando, Director General, Forest Department for permission granted to (AdS, AB and CA) (FRC/5 and FRC/6) to conduct the above study. Director General, Department of Wildlife Conservation, Mr. H. D. Rathnayake for approvals (WL/3/2/1/14/12). The Forest Department officers at Loolwatte and Illukumbura for their friendly support throughout the study. Manel Goonasekera, Head Department of Biological Sciences, Rajarata University of Sri Lanka for her support from the inception of the project.

University of Edinburgh, UK for funding and supporting project knuckles 2004 undergraduate research expedition (especial thanks the following University of Edinburgh Funds: Aranmore Memorial Travelling Scholarship, Davis Fund, James Rennie Bequest, Student Travel Fund, Weir Fund, William Dickson Travelling Fund and also British Student Travel Fund, Edinburgh No 2 Fund, Gilchrist Educational Trust, Lindeth Charitable Trust, Peoples Trust for Endangered Species, Royal Geographical Society Expedition Research Grant
(Gumby Award). We also thank Alasdair Ford, Andrew Burns, Douglas Fraser, Laura Packham and Polly Bramham from the Project Knuckles 2004 for helping to gather data in the field.

Roger Meek helped with data analysis.

Literature cited

Allmon, W. D. 1991. A plot study of forest floor frogs, Central Amazon, Brazil. *Journal of Tropical Ecology*, 7: 503-522.

Ashton, M., S. Gunatilleke, N. DE Zoysa, M. D. Dassanayake, N. GUNATILLEKE & S. Wijesinghe. 1997. *A field guide to the common trees and shrubs of Sri Lanka*. WHT Publishers (Pvt.) Ltd. 432 pp.

Bickford, D. P. 1994. Diversity and abundance of a montane leaf-litter herpetofauna in Costa Rica: implications of elevational patterns. *Abstracts, Second World Congress of Herpetology*, University of Adelaide, Australia. p.11

Central Environmental Authority (1997) *Wetland site report and conservation management plan, Horton Plains National Park.* CEA/Euroconsult. 70 pp.

Das, I. & Anslem de Silva. 1998. Species diversity and species richness of the leaf litter herpetofauna in Sri Lanka: preliminary results. In: *Biology and conservation of the amphibians, reptiles and their habitats in South Asia.* pp. 285-293.

Das, I. 1996. Spatio-temporal resource utilization by a Bornean rainforest herpetofauna: preliminary results In: D Edward's, W Booth & S Choy (Eds.) Tropical rainforest research: current issues. pp. 315-323. Kluwer Academic Pub. Dordrecht.

Dutta, S. K. & K. Manamendra-Arachchi. 1996. *The amphibian fauna of Sri Lanka* Wildlife Heritage Trust of Sri Lanka. 230 pp.

Ginige, P. 1994., Reptile Fauna of knuckles range, Sri Lanka. *Lyriocephalus* 1 (1&2) 38-43

Heinen, J. L. 1992. Comparison of the leaf-litter herpetofauna in abandoned cacao plantations and primary rain forests in Costa Rica: some implications for faunal restoration. *Biotropica* 24(3): 431-439

Herath, N. D., N. D. Rathnayake & K. Hewamathes, 2001. Some observations on the amphibians in Uduwattakele Sanctuary, Kandy. *Lyriocephalus*, 4(1 & 2): 116-120.

Inger R F (1980a) Densities of floor-dwelling frogs and lizards in lowland forests of Southeast Asia and Central America. *American Naturalist* 115(6): 761-770.

Inger, R. F. 1980. Reletive abundance of frogs and lizards in forests of Southeast Asia. *Biotropica* 12(1): 14-22

Jaeger, R. G. & R. F. Inger. 1994. Quadrate sampling. In: *Measuring and monitoring biological diversity: standard methods for amphibians.* pp. 97-102. W A Heyer et al (Eds.) Smithsonian Institute, USA.

Lloyd, M. R. F., Inger & F. W. King. 1968. On the diversity of reptiles and amphibian species in a Bornean rain forest. *American Nat.* 102: 497-515.

Manamendra-Arachchi, K. & R. Pethiyagoda. 2005. The Sri Lankan shrub-frog of the genus *Philauts* Gistel, 1848 (Ranidae: Rhacophorinae), with description of 27 new species. *The Raffles Bulletin of Zoology*. Supplement 12.: 163-303. .

Meegaskumbura, M. & K. Manamendra-Arachchi 2005. Description of eight new species of shrub-frogs (Ranidae: Rhacophorinae: *Philautus*) from

Sri Lanka.*The Raffles Bulletin of Zoology.* Supplement 12.: 305- 338.

Petiyagoda, R. & K. Manamendra-Arachchi. 1998. Evaluating Sri Lanka's Amphibian Diversity – Occ Paper, of Wildlife Heritage Trust of Sri Lanka : No 2, 1 – 12

Rathnayake N.D, A. N. Weerasinghe, K. Amarasinghe, C. Gamlath, C. Irrugalarathne, D. Rathnayake & H. Wijesinghe. 1999. *An ecological study on flora & fauna of Knuckles range, Sri Lanka (Northern region),* Youth Exploration Society of Sri Lanka, Peradeniya, 25 – 28.

Rathnayake, N. D. 2001. Notes on some amphibians observed In Knuckles Range. *Lyriocephalus,* 4(1 & 2): 121-123.

Rochs, C. F. D., M. V. Sluys, M. A. S. Alves, H.G. Berallo & D. VRCIBRADIC. 2001. Estimates of forest florr litter frog communities: a comparison of two methods. *Abstracts 4th World Congress of Herpetology, Sri Lanka.* P. 147.

Weerakoon, W. M. S. K. 2001. Comparative richness of amphibians inhabiting the islands at Randenigala reservoir with mainland of the Victoria Randenigala Ranambe (VRR) sanctuary. . *Lyriocephalus,* 4(1 & 2): 124-129.

Table 2
Leaf litter plot data

plot No	Habitat	Altitude	1	2	3	4	5	6	7	8	9
1	Pine	1300	Nil	Nil	Nil	N il	2	7m, 6f	Nil	Nil	Nil
2	Pine	1300	Nil	Nil	Nil	N il	Do	5m, 6f	Nil	Nil	Nil
3	Pine	1227	2m 2f	Nil	Nil	Nil	Nil	1m, 6f, 2NS, 6 eggs	Nil	1 NS	2
4	Pine	1134	Nil	Nil	Nil	Nil	Nil	16NS	1NS	Nil	2
5	Pine	984	Nil	Nil	Nil	Nil	2	1m, 1f	Nil	Eggs	Nil
6	Monsoon forest		Nil	Nil	Nil	Nil	Nil	Nil	Nil	Eggs	Nil
7	Ditto		Nil	1m.1f	Nil	4 NS	Nil	7 NS	Nil	1f	Nil
8	Burnt pine	1300	Nil	Nil	Nil	Nil	1	5 NS	Nil	Nil	Nil
9	Burnt pine	1201	Nil	Nil	Nil	Nil	Nil	3 NS, 1f	Nil	1	Nil
10	Pine	1155	Nil	Nil	1m	Nil	Nil	2m. 1f 2 NS	1m 1NS	1 + eggs	Nil
11	Abandoned										
12	Cardamom	1251	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	4
13	Cardamom	1250	1m, 2f, 1juven	2 NS	1m	Nil	2	1m, 2f, 5NS	Nil	Nil	2
14	Cardamom	1300	1m, 1f, 1NS	Nil	Nil	Nil	1f	4m, 7 NS	1m, 1NS	1	5
15	Disturbed cloud forest		1m, 1J	Nil	Nil	Nil	Nil	1 NS	Nil	Nil	3
16	Ditto		1m	1NS	Nil	Nil	Nil	1m, 2NS	Nil	1	4
17	Ditto	838	Nil	Nil	Nil	Nil	Nil	1 NS	Nil	Nil	1
18	Ditto	933	Nil	Nil	Nil	Nil	Nil	1NS	Nil	1	21
19	Cardamom	1179	1 ju	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
20	Disturbed cloud forest	1198	2 NS	Nil	Nil	Nil	Nil	Nil	Nil	Nil	3

21	Ditto	1230	1f	Nil	Nil	Nil	Nil	1NS	Nil	Nil	Nil
22	Cardamom	1153	1f, 2NS	3	Nil	Nil	Nil	1NS	Nil	Nil	2
23	Cardamom	1372	Nil	Nil	Nil	Nil	Nil	2 NS	Nil	Nil	1
24	Acacia	1095	Nil	Nil	Nil	1	3	Nil	1m, 1f	Nil	Nil
25	Acacia	Do	Nil	Nil	Nil	Nil	2	1f, 1NS	1f, 1NS	Nil	Nil
26	Acacia	1122	Nil	Nil	Nil	Nil	Nil	1m, 1NS		2NS	Nil
27	Acacia		Nil	Nil	Nil	Nil	1	1m, 1f, 2 NS	3	1NS	3
28	Fragmented Monsoon forest	1025	Nil	Nil	Nil	1m	Nil	2m, 3f, 4NS	Nil	Nil	3
29	Fragmented forest	981	Nil	Nil	Nil	Nil	Nil	1	1	Nil	Nil
30	Riverine	1065	Nil	Nil	Nil	1	Nil	1f, 4NS	1	Nil	1
31	Riverine		Nil	Nil	Nil	Nil	1m, 2f, 1NS	Nil	Nil	Nil	Nil
32	Riverine		Nil	4	Nil	Nil	Nil	1NS	Nil	1NS	Nil
33	Riverine		Nil	1f, 1NS	Nil	Nil	Nil	1m, 1f	Nil	Nil	1
34	Riverine		Nil	2NS	Nil	Nil	Nil	1f, 2NS	Nil	2NS	5
35	Riverine		Nil	1f	Nil	Nil	Nil	Nil	Nil	1NS	
36	Riverine		Nil		Nil	Nil	Nil	1m	Nil	Nil	1
37	Monsoon forest		Nil	1f	Nil	Nil	Nil	Nil	Nil	Nil	7
38	Ditto		Nil	1NS	Nil	Nil	Nil	4NS	Nil	Nil	Nil
39	Ditto		Nil		Nil	Nil	Nil	Nil	Nil	Nil	2
40	Ditto		Nil	1NS	Nil	Nil	Nil	Nil	Nil	Nil	6

Key: 1. *Ceratophora tennentii, 2. Chalcidoseps thwaitesii 3. Cyrtodactylus soba, 4. Nessia bipes, 5. Uropeltis melanogaster, 6. Lankascincus, 7. Geckoella triedra , 8. Cnemaspis.* 9. amphibians NS = not sexed.

The Diversity of the Dumbara Mountains (The Knuckles Massif, Sri Lanka): With special reference to its herpetofauna.
Lyriocephalus Special issue, 2005 November, Volume 6 Numbers 1 & 2: 43-52
ISSN 1391–0833

STATUS OF THE AGAMIDS IN THE KNUCKLES MASSIF WITH SPECIAL REFERENCE TO *CALOTES LIOCEPHALUS* GÜNTHER, 1872 AND *COPHOTIS CEYLANICA* PETERS, 1861

Anslem de Silva[1], Aaron Bauer[2], Suraj Goonewardene[3], John Drake[3], Shirani Nathanael[4], W.P.R.Chandraratne[4], and S.A.U.S. Somathilaka[4]

[1]15/1 Dolosbage road, Gampola, Sri Lanka. Email: kalds@sltnet.lk
[2]Department of Biology, Villanova University, 800 Lancaster Avenue, Villanova, Pennsylvania 19085, USA. Email: aaron.bauer@villanova.edu
[3]97, Battersea Park Road, London, SW9 4DU, UK. E-mail: hsr.wild@gmail.com (University of Edinburgh, UK)
[3]Creagard, Isle of Mull, PA75 6RA, UK. E-mail: jfdrake@gmail.com (University of Edinburgh, UK)
[4]Department of Biological Sciences, Rajarata University of Sri Lanka

Keyword: Agamids, *Calotes, Cophotis, Otocryptis*, threats, Knuckles

Introduction

Based on the findings of the Knuckles Expeditions of 2004 and 2005, the Knuckles ecosystems could now be ranked as a great herpetological hotspot in the country. Not only does it have a high amphibian and reptile diversity of which most are endemic, but it is also rich in vegetation, climatic and altitudinal variations.

The agamids constitute a diverse and attractive group of lizards. Presently 17 species are known from the country (Bahir & Maduwage, 2005; Bahir & Silva, 2005, Das & de Silva, 2005) of which species of the genus *Ceratophora, Lyriocephalus* and *Cophotis* are considered as geographical relicts (Crusz, 1986). First described by Günther and Gray in 1861 in Sir Emerson Tennant's book 'Sketches of the Natural History of Ceylon' *Ceratophora tennentii* is unique as it is confined to the Knuckles mountain range. A detailed account of it is reported in the present issue (see de Silva *et al.*, 2005d). At present *Ceratophora tennentii* and *Calotes liocephalus* are the only agamids that are listed in the IUCN Red List of threatened animals. Though *Calotes liocephalus* is known from outside the Knuckles massif, its main populations are confined to the Knuckles.

During the Knuckles expedition ten agamid species (including a colour variant of *Calotes calotes*) were studied. The present paper focuses on the status of agamids in the Knuckles ecosystem. It is envisaged that this investigation will stimulate further research and studies into the natural history and distribution of these agamids and encourage the initiation of effective management and conservation strategies by the relevant government departments.

Methodology

The main field techniques employed during this study were:
Patch and quadrat sampling, visual encounter survey and canopy investigations.
Upon observation and where possible, most agamids were collected and the following data was recorded in a structured questionnaire form: date, time, GPS location, locality, habitat, microhabitat, species, gender, measurements, defects of the agamid (if any) and any further observations on morphology or behaviour. After recording details and photographing, the animal was re-released in the location from where it was collected.

Results

The agamid species observed and the field notes recorded during the Knuckles expedition are listed below:

Family Agamidae Gray, 1827

Genus: *Calotes* Cuvier, 1817.

1. *Calotes calotes* (Linnaeus, 1758). English: Green Garden Lizard, Sinhala: Pala Katussa = Green Lizard, Tamil: Pachai Karata = Green Lizard. Status: Not Endemic.

Notes: Over one hundred specimens of *Calotes calotes* were observed during the expedition. The species was observed throughout the entire Knuckles range, up to 1 400m above mean sea level. They were encountered on low vegetation on the banks of rivers, streams and irrigation channels. They were also observed on low vegetation along paths and roads and in anthropogenic habitats. In July 2005 we observed five *Calotes calotes* females laying eggs on the Narangamuwa - Lakegala trail. The females fled when disturbed and deposited a number of eggs whilst running. Agamids observed sympatric to the species were: *Lyriocephalus scutatus, Otocryptis* sp, *Ceratophora tennentii, Calotes versicolor* and *C. liolepis.*

Additionally, two distinct colour variations of *Calotes calotes* was observed in the Knuckles (Plate 2. Figure 1). Presently work is in progress in order to ascertain their identity.

2. *Calotes ceylonensis* (Müller, 1887). English: Painted Lip Lizard, Sinhala: Thola-visituru Katussa. Status: Endemic.

Notes: This agamid was mainly confined to the monsoonal forests of the northeastern (Laggala-Pallegama,Kaikawela, Kiwlewadiya, Bathalwatte, Puwakpitiya) and eastern (Yahangala) parts of the Knuckles. It was mainly confined to the edges of forests and was also observed in home gardens,

mainly on the trunks of mango trees. Approximately 25 specimens were observed during the expedition.

3. *Calotes liocephalus* (Günther, 1872). English: Crestless Lizard, Sinhala: Kondu Datirahita Katussa. Status: Endemic.

Notes: Though this agamid is reported from Peradeniya, Agrapathana and Pundalu Oya (Deraniyagala, 1953), appreciable populations were observed in the Knuckles. Thirty four specimens were observed during the expedition, suggesting that *Calotes liocephalus* (Plate 3. Figures 2 & 3) is not uncommon in the Knuckles region. It was observed around Dumbanagala (1049m), Sphinx Rock (1359m), Nawanagala (1199m), Corbet's Gap (1021m), Kobonilagala (1458m), Thangappuwa (1300m), Rangala (1164m) and Gammaduwa (1115m). Of the 34 specimens, 7 were male and 17 female. 6 were unsexed juveniles, while the gender of 4 could not be checked as they could not be caught. Specimens were observed at altitudes ranging from 900 to 1400 m above mean sea level and were found on the edges of branches of large forest trees as well as on shrubs in the under storey. Though it was earlier considered a montane forest species, which inhabited only pristine habitats, we observed it in highly degraded areas including tea plantations and home gardens It was also common on trees and low vegetation in cardamom plantations. 5 gravid females were observed in July 2005. During the expedition period three dead adult *Calotes liocephalus* males were observed on the Loolwatte - Meemure road having been run over by road traffic (Plate 2. Figure 8). *Calotes calotes* females can easily be misidentified as a *Calotes liocephalus* female.

The microhabitats of *Calotes liocephalus* when first observed are given in Table 2. The species' preferred habitat type is the upper montane forest (Table 3).

Note: all habitats were highly disturbed.

4. *Calotes liolepis* (Boulenger, 1885). English: Whistling Lizard, Forest Lizard, Sinhala: Sivuruhandalana Katussa. Status: Endemic.

Calotes liolepis (Plate 2. Figure 4). was observed throughout the Knuckles mountain range from around 300 m up to 1300 m above mean sea level. The mean altitude at

which they were observed was 863.7 m. They were observed at an altitude range of 434 to 1458 m on and around Dumbanagala (1132m), Lakegala (434m), Corbet's Gap (1223m), Dawatagala (1344m), Deanston (816m), Dotalugala (1227m), Kalupahana (1002m), Kandegama (750m), Keena-Gommana (933m), Kobonilagala (1191m), Laggala – Pallegama (571m), Loolwatte (1191m), Nitre caves (662m), Pitawala (846m), Pitawala Patana (919m), Puwakpitiya (550m), Kobonilla (1025m) and Udadumbara (500m)

Fifty specimens were observed, and 38 specimens were investigated in detail: 23 were female, 8 were male and the gender of the rest could not be investigated as they escaped. It was notable that no juveniles were observed during the survey of 2004 and 2005.

Calotes liolepis was usually detected on the trunks of tall trees, about 10 m above ground level. *Calotes liolepis,* though a forest species was also observed in monoculture plantations (*Pinus, Acacia* and Cardamom) in the Knuckles. They could be seen on large tree trunks by the road side as well as in home gardens (Table 5 and 6). *Calotes liolepis* is extremely clever in evading humans. Usually when on branches they conceal themselves well, and only a person who knows their habits can detect them. At several locations the team (usually 7-10 persons) could not find any specimens whilst conducting field work. However, when checking the same locality in the night with flashlights, several sleeping *Calotes liolepis* were detected at the edges of branches from 3 to 5 meters above the ground. We thus feel that the best time to check for this agamid is in the night using a flash light.

Two male *C. liolepis* were observed dead on the road along a pine plantation (*Pinus carebea*) have been run over by road traffic.

5. *Calotes versicolor versicolor* (Daudin, 1802). English: Common Garden Lizard, Sinhala: Gara Katussa (= house lizard). Status: Not Endemic.

Notes: This "weed species" was observed throughout the Knuckles massif, mainly in anthropogenic habitats, although it was observed to have invaded pristine habitats as well. Preliminary observations of the *Calotes versicolor versicolor* population inhabiting Pitawala Patana indicated that the population here appeared different from the *Calotes versicolor versicolor* inhabiting other lowland localities in the Knuckles range.

6. *Ceratophora tennentii* (Günther and Gray, 1861). English: Leaf-nosed Lizard, Sinhala: Pethi Angkatussa. Status: Endemic.
Notes: During the survey 340 specimens (Males 72 (21.2 %), females 58 (17.1 %), un-sexed 174 (51.2 %) and un-sexed juveniles 36 (10.6 %) of *Ceratophora tennentii* were observed. Accounts on the ecology of this relict agamid, its thermoregulatory habits, and parasites are given in this volume (de Silva *et al.,* 2005d; de Silva *et al.,* 2005e; de Silva *et al.,* 2005f).

Genus: *Cophotis* (Peters, 1861).

7. *Cophotis ceylanica* (Peters, 1861). English: Pygmy Lizard, Sinhala: Kandukara Kuru Katussa. Status: Endemic.
Notes: Recent observations have revealed that *Cophotis* (Plate 2. Figure 5) is extremely rare in this range although during many visits made by the first author to the Knuckles range, appreciable numbers were observed from the mid 1970's until the late 1980's. Recent investigations indicate that a distinct decrease in the numbers of *Cophotis ceylanica* has occurred. Intensive sampling made by the entire team (usually 7 to 10 persons at a given time) during Project Knuckles (2004 and 2005) only detected six specimens.
Deraniyagala (1953) records fluctuations in the population of some reptiles including *Cophotis*, but does not give any reasons for such fluctuations, however, in 1992 a catastrophic mortality of *Cophotis ceylanica* was observed around Hakgala (1,500 m) and Nuwara Eliya (1,800 m) where hundreds were found dead within a few days (de Silva 1996; de Silva 2001; Palihawadana 1998). Although post-mortem and other pathological examinations were not conducted to ascertain the cause of death, an

extended drought with high temperatures reported during this period is believed to have been a major contributory factor (de Silva 1996). According to Fernando and Chandrapala (1991) there has been an increase in temperature and a decrease in the annual rain-fall in these areas during the past century. It is possible that the *Cophotis ceylanica* populations in the Knuckles would also have faced the same fate as their counterpart populations in Hakgala and Nuwara Eliya.

Cophotis ceylanica is also known from Horton Plains, Hakgala and Nuwara Eliya (from 1600 to 2100 m above sea level). However, the population in the Knuckles is distinctly separated from the central montane stock, and has been for several thousand years, on account of major natural barriers such as the Dumbara valley. We feel that molecular studies (presently in progress) will show whether or not the population in the Knuckles is a distinct species.

Genus: *Lyriocephalus* (Merrem, 1820).
8. *Lyriocephalus scutatus* (Linnaeus, 1758). English: Lyre Head Lizard, Hump-snout Lizard, Sinhala: Gatahombu Katussa = Hump-snout Lizard, Karamal Bodiliya = Crested Lizard, Kandukara Bodiliya = Montane Lizard, Sondura = Beloved. Status: Endemic.

Notes: Some distinct differences in morphology and colour were observed in specimens inhabiting the lowland dryer parts in the north east of the Knuckles range when compared to those inhabiting the cool montane forests (Table 9). The mean altitude at which *L. scutatus* specimens were observed was 760.7 m above mean sea level.

Genus: *Otocryptis* (Wagler, 1830).
9. *Otocryptis nigristigma* Bahir & Silva, 2005. English: Black-spotted Kangaroo Lizard, Sinhala: Kaka Lapawan Tali Katussa = Black-spotted Pendant Lizard; Pinum Katussa = Jumping Lizard, Tali Katussa = pendant lizard, Kala Katussa. Status: Endemic.

Notes: This recently described agamid was observed during the survey and was mainly confined to the dry northeast lowland forests of the Knuckles. A conspicuous external identification feature of *Otocryptis nigristigma* (Plate 2. Figure 6) is the black spot on the dewlap, in contrast to the orange spot found in *Otocryptis wiegmanni* (Bahir & Silva, 2005). Its specific name "*nigristigma*" has been coined from the Latin, nigra meaning black and stigma meaning mark (Bahir & Silva, 2005).

In some areas (Puwakpitiya) we observed a mixture of specimens with either an orange or a black spot on the dewlap, indicating an overlap of the two populations.

10. *Otocryptis wiegmanni* Wagler, 1830. English: Orange-spotted Kangaroo Lizard, Sinhala: Gomu Tali Katussa = Forest Pendant Lizard; Pinum Katussa = Jumping Lizard, Tali Katussa = Pendant Lizard, Kala Katussa = Forest Lizard. Status: Endemic.
Notes: Over 100 specimens were observed at many locations in the south and central Knuckles. They were found on the forest floor, rocks, the roots of large trees, low vegetation and even on boulders along streams. *Otocryptis wiegmanni* (Plate 2. Figure 7) was observed inhabiting an altitude range of 400 to 1250 m.

Status of agamids at Knuckles
During the expedition, excluding *Cophotis ceylanica* healthy populations of the other agamid species (especially *Ceratophora tennentii*) were observed occupying forests, plantations, and anthropogenic habitats. However, due to over exposure in plantations and anthropogenic habitats agamids and other fauna face many threats.

Threats
The biggest threats facing agamids include habitat loss through deforestation, habitat alteration and habitat fragmentation, which are caused during the establishment of plantations and settlements. Vast tracts of primary forest up to altitudes over 1000 m were first cleared in the mid 19th century for the cultivation of coffee and tea. However, despite the failure of coffee, and gradual reduction in the production of tea in the

Knuckles, large-scale agricultural practices continue in the mountains. Despite land above the 1067 m contour line being currently designated as a conservation forest, the forest here continues to suffer damage. The cultivation of cardamom (*Ellettaria cardamomum*) in the area increased considerably from the 1960s until the recent ban. This type of cultivation requires that the farmer clear the under storey and several large trees in a forest, leaving only a select few trees to provide shade and shelter for the cardamom.

We feel that the impact of these large scale alterations to the natural forest will take effect upon the resident species for at least another few decades before the forest can recover to some form of its original status. Furthermore, and perhaps attributed to these vast forest clearances, increasing temperatures and a decreasing annual rainfall has been recorded as a trend in Sri Lanka in the recent past (Fernando & Chandrapala, 1991).

These forests contain the most distinctive and conservative elements of Sri Lanka's reptilian fauna. They have been least influenced by recent invasions from the Indian mainland (Crusz 1984). They require priority in terms of protection. Thus, we feel that the Forest Department and other relevant government and non-governmental organizations should initiate a programme or series of programmes to properly conserve these forests. Immediate attention should be paid to prolific spread of certain weed species in the region and imminent action should be taken to eradicate the rapid spread of weeds such as Lantana (*Lantana camara*) and Mistflower (*Eupatorium reparium*). The latter was first imported to the Hakgala Botanical gardens in 1900 and subsequently spread throughout the central hills. This weed has now spread to the Knuckles and is widely distributed throughout the ecosystem. It is possible to envisage that this weed will eventually cover the entire forest floor, depriving ground-feeding agamids (such as *C. Lyriocephalus* which feeds mostly on earthworms, grubs and other insects) of their prey.

Population growth and Predators

Domestic cats (*Felis cattus*), poultry, and the Common Coucal (*Centropus sinensisi*) are known predators of agamids. With increasing human populations and the construction of additional houses bordering the Knuckles conservation area, the population of domestic cats and poultry have also been increasing substantially, posing a notable threat to agamids.

Furthermore the considerable increase in distribution of the common agamid: *Calotes versicolor versicolor* into forests may be an additional threat. It is well known to predate on juvenile Rhino-horned lizards (*Ceratophora stoddartii*) (Senanayake 1980) and on young *Sitana ponticeriana*. *Calotes nigrilabris* have also been observed to feed on young *Cophotis ceylanica* (de Silva, 2001). Although this *Calotes* species is not present in the Knuckles Mountains, this indicates nonetheless that agamids are certainly capable of eating one another.

Forest fires

Each year, hundreds of hectares of forest, grassland and pine plantations are set on fire in the Knuckles region (Plate 9 Figure 7). These fires may pose a serious threat to the resident reptiles, including their eggs which are laid in the humus and under leaf litter. Several burnt agamids were observed following such fires during the expedition (Plate 9. Figure 8).

Agrochemical use

During the survey we observed the widespread use of pesticides throughout the conservation area as well as in tea plantations on the periphery. Although there is no data regarding the direct effects of pesticides on agamids, it is suspected that application has an adverse affect as the chemicals target most of the prey species of the lizards.

Road kills

An appreciable number of dead agamids were observed having been run over by road traffic (Plate 2. Figure 8).

Smuggling

Despite the Fauna and Flora Protection Ordinance (Amendment- Schedule 1) stipulating that all of Sri Lanka's reptiles are protected, there is evidence that agamids have been smuggled out of the country.

Acknowledgements

We wish to thank: Mr. Sarath Fernando, Director General, Forest Department for permission granted to AdS, AB and CA (FRC/5 and FRC/6) to conduct the above study. Director General, Department of Wildlife Conservation, Mr. H. D. Rathnayake for approvals (WL/3/2/1/14/12). The Forest Department officers at Deenston and Illukumbura for their friendly support throughout the study.

The University of Edinburgh, UK for funding and supporting Project Knuckles 2004 and 2005 an undergraduate research expedition (special thanks to the following University of Edinburgh Funds: Aranmore Memorial Travelling Scholarship, Davis Fund, James Rennie Bequest, Student Travel Fund, Weir Fund, William Dickson Travelling Fund and also British Student Travel Fund, Edinburgh No. 2 Fund, Gilchrist Educational Trust, Lindeth Charitable Trust, Peoples Trust for Endangered Species, Royal Geographical Society Expedition Research Grant (Gumby Award). BP (British Petroleum) for the generous grant.

Finally the University of Edinburgh students: Polly Bramham, Alasdair Ford, Douglas Fraser, Laura Packham, and A. J. G. Burns for their support in the field.

Literature cited

Bahir, M. M. & K. P. Maduwage 2005. *Calotes desilvai*, a new agamid lizard from Morningside Forest, Sri Lanka. *The Raffles Bulletin of Zoology*, 12: 134-150s

Bahir, M. M. & A. Silva. 2005. *Otocryptis nigristigma*, a new species of agamid lizard from Sri Lanka. In: Yeo, D. C. J., P. K. L. Ng & R. Pethiyagoda (eds.), Contributions to biodiversity exploration and research in Sri Lanka. *The Raffles Bulletin of Zoology*, 12, 235-241.

Crusz, H. 1984. Parasites of endemic and relict vertebrates: a biogeographical review. In: *Ecology and Biogeography in Sri Lanka* (Ed.) C. H. Fernando. Dr. W. Junk Publishers, The Hague. pp.321-351

Crusz, H. 1986. The vertebrates of Sri Lanka: endemism and other aspects. *Rep. Soc. Res. Native Livestock* 11: 65-85

Das, I. & Anslem de Silva. 2005. *Photographic guide to snakes and other reptiles of Sri Lanka.* New Holland, UK, 144 pp.

de Silva, Anslem. 1996. *The herpetofauna of Sri Lanka a brief review.* Published by the Author. Printed at Graphic Land, Kandy. 99 pp.

de Silva, Anslem., S. Molur & S. Walker. 2000. *Conservation Assessment and Management Plan CAMP Report for amphibians and selected taxa of reptiles of Sri Lanka.* Conservation Breeding Specialist Group, Sri Lanka. 226 pp.

de Silva, Anslem. 2001. *The Herpetofauna of Sri Lanka: historical aspects and current status.* Ministry of Environment, 100 pp

de Silva, Anslem, A. Bauer, C. C. Austin, S. Goonewardene, J. Drake & M. M. Goonasekera. 2005d. *Ceratophora tennentii* Günther & Gray, in Tennent, 1861 (Reptilia: Agamidae) some notes on its ecology. *Lyriocephalus* Special issue, 2005, Volume 6 Numbers 1 & 2.

de Silva Anslem, R. Meek, A. Bauer, S. Goonewardene, J. Drake, R. D. C. S. K. Dasanayaka, A.M.R.K. Amarakoon & M. M. Goonasekera. 2005e. First studies on the thermal ecology of *Ceratophora tennentii*: (Sauria: Agamidae) inhabiting the cloud forests of the Knuckles massif, Sri Lanka. *Lyriocephalus* Special issue, 2005, Volume 6 Numbers 1 & 2.

de Silva, Anslem, R. P. V. J. Rajapaksa, R.R.M.K.K. Wijesundera, A. Bauer, S.Goonewardene, J. Drake, M. de Silva and N. A. N. D. Perera. 2005f. Preliminary investigations of the parasites of agamids inhabiting the Knuckles mountain range, with special reference to *Ceratophora tennentii* (Reptilia: Agamidae). *Lyriocephalus* Special issue, 2005, Volume 6 Numbers 1 & 2.

Deraniyagala, P. E. P. 1953. *A Colored atlas of some vertebrates from Ceylon, Vol.2, Tetrapod reptilia.* Ceylon National Museum, 101 pp.

Fernando, T. K. & L. Chandrapala. 1991. Global warming and rainfall variability - Sri Lanka situation. *Proc. 47th Ann. Ses. Sri Lanka Assoc. Adv. of Sci.* Part., 1 : 138.

IUCN Sri Lanka. 2000. *The 1999 list of threatened fauna and flora of Sri Lanka*. Colombo: IUCN Sri Lanka. 114 pp.

Palihawadana, A. 1998. An ecological study of *Cophotis ceylanica*. IN: *Biology and Conservation of the Amphibians, reptiles and their habitats in South Asia.* (Ed.) Anslem de Silva, 253-260.

Senanayake, F. R. 1980. The status of the endemic lizards, genus *Ceratophora* in Sri Lanka *Tigerpaper.* 7(4): 26-2

Table 1
Some measurements of *Calotes liocephalus*
(Knuckles expedition – 2004 and 2005)

Sex	SV (mm)		Tail (mm)		Total length (mm)		Weight (g)	
	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range
Female	75.13±13.86	52-96	192±34.8	135-237	263.4±43.7	203-317	13±4.9	7-19
Male	84.25±14.8	65-100	240±34.8	186-275	324.5±52.4	251-375	14.75±10.25	7.5-22

Table 2
Microhabitat of *Calotes liocephalus*
(Knuckles expedition – 2004 and 2005)

Microhabitat	Number observed	Percentage
Live tree (branch)	8	32
Dead tree	2	8
Fern	1	4
Leaf litter	2	8
Low vegetation	7	28
On wall	1	4
Tree stem	2	8
Road	1	4
Tea bush	1	4

Table 3
Habitat of *Calotes liocephalus*
(Knuckles expedition – 2004 and 2005)

Habitat	Number observed	Percentage
Upper Montane Forest	17	68
Lower Montane Forest	4	16
Abandoned Human Habitation	3	12
Tea Plantation	1	4

Table 4
Morphometry of *Calotes liolepis*
(Project Knuckles – 2004 and 2005)

Sex	SV (mm)		Tail (mm)		Total length (mm)		Weight (g)	
	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range
Female	75.87±12.57	47-97	177.8±72.1	90-386	253.7± 80.1	139-483	11.16±3.88	5.1-16
Male	82.67±16.44	60-106	181±120.2	17.5-386	255.2±138.5	92-483	13.85±6.09	6-20

Table 5
Habitat of *Calotes liolepis*
(Project Knuckles – 2004 and 2005)

Habitat	**Number observed**	**Percentage**
Upper Montane Forest	1	2.6
Lower Montane Forest	17	44.7
Patana	2	5.3
Pine plantation abandoned	3	7.9
Riverine Forest	1	2.6
Tropical Mixed Evergreen Forest	13	34.2
Human Habitation	1	2.6

Table 6
Microhabitat of *Calotes liolepis*
(Project Knuckles – 2004 and 2005)

Microhabitat	Number observed	Percentage
Dead branch	4	10.5
Dead vine	2	5.3
Ground	1	2.6
Inside tree hole	1	2.6
Leaf litter	1	2.6
Low vegetation	2	5.3
Path	1	2.6
Road	1	2.6
Tree	25	65.8

Table 7
Measurements of *Lyriocephalus scutatus*
(Project Knuckles – 2004 and 2005)

Sex	Total length (mm)		Weight (g)	
	Mean ± SD	Range	Mean ± SD	Range
Female	216.4±34.1	160-245	33.4±18.05	6-54
Male	Not recorded	203-301	4417±8.6	38.54
Juvenile	70.67±1.5	69-72	2.17±0.29	2-2.5

Table 8
Habitat of *Lyriocephalus scutatus*
(Project Knuckles – 2004 and 2005)

Habitat	Number observed	Percentage
Lower Montane Forest	6	31.6
Tropical Mixed Evergreen Forest	12	63.2
Clove Plantation	1	5.3

Table 9
Mcirohabitat of *Lyriocephalus scutatus*
(Project Knuckles – 2004 and 2005)

Microhabitat	Number observed	Percentage
Tree	4	21.1
Ground	1	5.3
Leaf litter	2	10.5
Low vegetation	1	5.3
Tree stem	9	47.4
Under log	1	5.3
Under rock	1	5.3

Table 10
Agamid species observed by various authorities in the Knuckles

Lizard species	IUCN & Forest Dept. 1994	Ginige, 1994	Rathnayake *et al*, 1999	Bambaradeniya & Ekanayake, 2003	De Silva, 2005	Present Study 2005
Calotes calotes	Observed	Observed	Observed	Observed	Observed	Observed
C. ceylonensis	Observed	Observed	Observed	Not	Observed	Observed
C. liocephalus	Observed	Observed	Observed	Observed	Observed	Observed
C. liolepis	Observed	Observed	Observed	Observed	Observed	Observed
C. versicolor	Observed	Observed	Observed	Observed	Observed	Observed
Ceratophora tennentii	Observed	Observed	Observed	Observed	Observed	Observed
Cophotis ceylanica	Not	Not	Not	Observed	Observed	Observed
Lyriocephalus scutatus	Observed	Observed	Not	Observed	Observed	Observed
Otocryptis wiegmanni	Observed	Observed	Not	Observed	Observed	Observed
Otocryptis nigristigma	Described in 2005	Described in 2005	Described in 2005	Described in 2005	Described in 2005	Observed

Plate 2

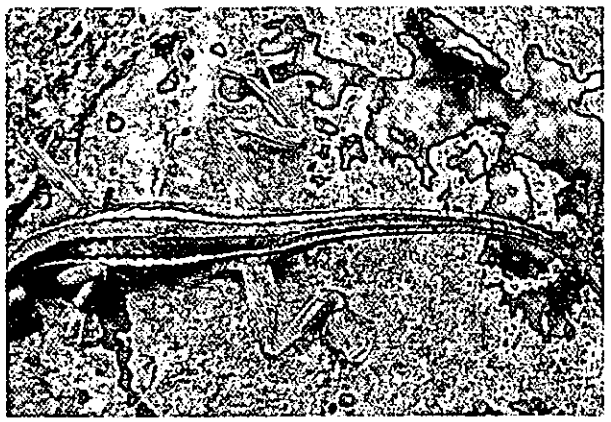


Figure 1. *Calotes calotes* (colour variation)

Figure 2. *Calotes liocephalus* (male)

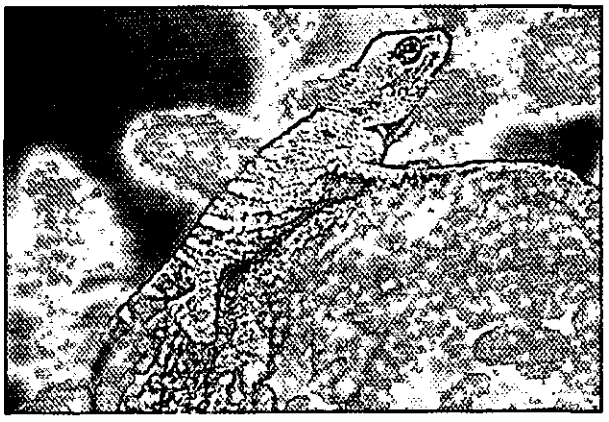


Figure 3. *C. liocephalus* (female)

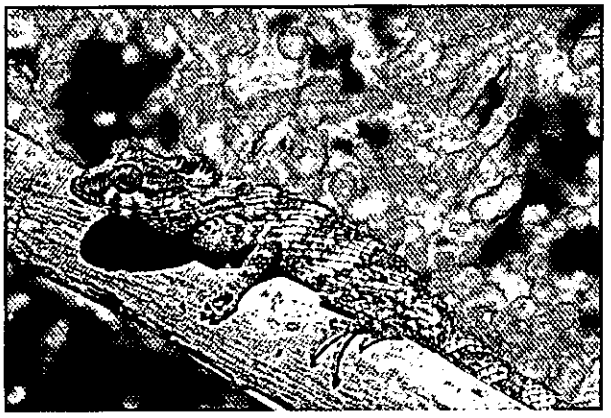


Figure 4. *C. liolepis*

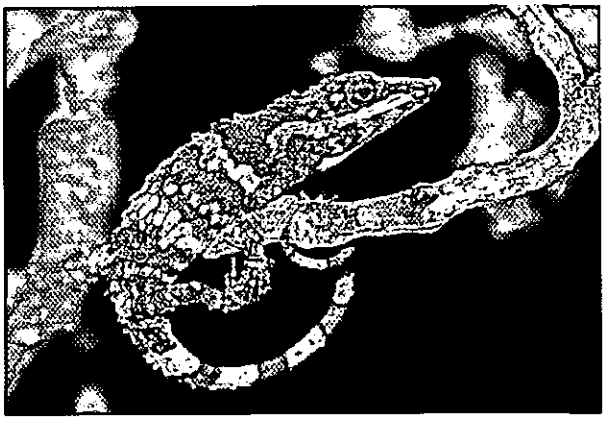


Figure 5. *Cophotis ceylanica*

Figure 6. *Otocryptis nigristigma*

Figure 7. *Otocryptis wiegmanni*

Figure 8. *C. liocephalus* road kill

Photographs: © Suraj Goonewardene and Anslem de Silva

The Diversity of Dumbara Mountains (Knuckles Massif, Sri Lanka): With special reference to its herpetofauna. *Lyriocephalus* Special issue, 2005 November, Volume 6 Numbers 1 & 2: 55-62
ISSN 1391–0833

CERATOPHORA TENNENTII GÜNTHER & GRAY, IN TENNENT, 1861 (REPTILIA: AGAMIDAE) SOME NOTES ON ITS ECOLOGY

Anslem de Silva[1], S. Goonewardene[2], A. Bauer[3] and J. Drake[2]

[1]15/1 Dolosbage road, Gampola, Sri Lanka. Email: kalds@sltnet.lk
Pennsylvania 19085, USA. Email: aaron.bauer@villanova.edu
[2]97, Battersea Park Road, London, SW9 4DU, UK. E-mail: hsr.wild@gmail.com (University of Edinburgh, UK)
[2]Creagard, Isle of Mull, PA75 6RA, UK. E-mail: jfdrake@gmail.com (University of Edinburgh, UK)
[3]Department of Biology, Villanova University, 800 Lancaster Avenue, Villanova

Keywords: *Ceratophora tennentii,* distribution, Knuckles, food habits, threats.

Introduction

The family Agamidae is represented in Sri Lanka by six genera, of which *Ceratophora*, *Cophotis* and *Lyriocephalus* are endemic. The genus *Ceratophora* Gray, 1834 consists of five species (Pethiyagoda & Manamendra-Arachchi 1998). They are: *Ceratophora aspera* Günther, 1864; *Ceratophora erdeleni* Pethiyagoda & Manamendra-Arachchi 1998; *Ceratophora karu* Pethiyagoda & Manamendra-Arachchi 1998; *Ceratophora stoddartii* Gray, 1834 and *Ceratophora tennentii* Günther & Gray, 1861. The distribution of *Ceratophora* within the island is of interest as they exhibit a distinct distribution pattern in the three massifs in the country: the Knuckles Massif, the Central mountain range and the Rakwana mountain range. *Ceratophora tennentii* is restricted to the Knuckles Massif and is the dominant agamid species at the Knuckles. *Ceratophora stoddartii* is widely spread in some montane forests in the central mountains and *Ceratophora aspera* is the southern-most species of the Rakwana mountain range.

Both *Ceratophora erdeleni* and *Ceratophora karu* are only known from small populations inhabiting the Morningside Forest Reserve of the Sinharaja World Heritage Site; *Ceratophora aspera* and *Ceratophora stoddartii,* on the other hand, enjoy a larger area of occupancy, though highly fragmented in distribution. *Ceratophora tennentii* is widely distributed in the Knuckles Massif, including within the Knuckles Conservation Forest and Man and Biosphere Reserve. This 159 km^2 Knuckles Conservation Forest is owned by the Government of Sri Lanka and is administered by the Forest Department. However, some parts in the Knuckles are owned by private individuals and managed as cardamom and tea estates (refer de Silva *et al.,* 2005a reported in this volume for more details). *Ceratophora tennentii* was the first agamid from Sri Lanka to be included in the *IUCN Red List of Threatened Animals*. Thus, *Ceratophora tennentii* is an important animal for conservationists, wildlife managers and research workers and knowledge of its ecology and status is critical. However, except for a few brief accounts by Deraniyagala (1931, 1953), Pethiyagoda & Manamendra-Arachchi (1998), and a brief account on the foraging behaviour by Rodrigo and Jayantha (2004) nothing is known of this agamid. We are presenting for the first time data on some aspects of its ecology and the status of this geographical relict agamid, including a paper on its thermal ecology (de Silva *et al.,* 2005e reported in this volume).

Field Identification

Ceratophora tennentii can be distinguished from the other four species by the presence of a distinct flat leaf-like rostral appendage above the snout (less distinct in females) (Plate 3. Figures 1 & 2).

First reference and types

Ceratophora Tennentii A. C. L. Günther & J. E. Gray in: J. E. Tennent. 1861. Sketches

Natural History. Ceylon: p. 281.(Types: British Museum of Natural History 1946.8.27.32-36 (syntypes; fide Denzer et al., 1997), ZMB 4774, 5119, "Ceylon" (= Sri Lanka).

Methods and material

Study area:

The Knuckles Massif consists of four major forest types: Tropical Montane Wet forest, Dry Sub-Montane evergreen forest, Wet Sub-Montane evergreen forest and Lowland Wet Evergreen forest. It also has humid zone dry *patana* (grasslands) and plantations (e.g. tea, cardamom, chena and mono-culture pines). The average rainfall varies from 2540 to 5080 mm, and the temperature varies according to altitude, but above 1000 m it is around 18°C. Refer de Silva *et al* (2005a and Ratnayake (2005) reported in this volume for more details.

Field methods

The study was conducted from June to August 2004. Approximately 500 hours were spent in the field. In addition one of us (Ads) has been visiting the Knuckles during the past 20 years.

1. The field map used was the "Land use map of Knuckles Conservation area" compiled by Natural Resources Management Services, Polgolla. Prepared in 2004 .
2. Four survey techniques were used: visual encounter survey (VES), patch sampling, sampling in large (20 x 20 m) leaf litter quadrats and canopy sampling in different vegetation habitats.
3. The coordinates of all study sites, including the altitude, were recorded using a GPS instrument.
4. When a *Ceratophora tennentii* was located, it was observed for a few minutes without disturbing it, so as to observe its behaviour. The air temperature was recorded on a structured survey form at the same time.
5. The external body temperature of the animal was then recorded by lightly touching it with the 130 mm long stainless steel sensor probe of the digital thermometer (stainless steel sensor probe model ST-9263A/B/C), taking care not to disturb it. The animal was then captured gently by hand and, with minimal handling, the stainless steel sensor probe of the digital thermometer was inserted into the cloaca to record the cloacal temperature.
6. Immediately after taking the cloacal temperature, a stool sample was collected into a plastic vial containing 10% formaldehyde solution. A field number was written on the surface of the vial for identification. These were later sent to the Parasitology section of the Faculty of Veterinary Studies, University of Peradeniya.
7. The gender of the animal, length from the tip of the snout to the vent (SVL), and tail length were recorded in millimeters using a micromatic 1 m steel tape. Reproductive status (gravid or not), presence of ecto-parasites and physical defects (missing tail tip etc) if observed were also recorded on the survey form.
8. Stomach contents were obtained from randomly selected animals for analysis. Distilled water was gently squirted into the stomach through an intragastric canula, while the mouth of the animal was held downwards, thereby flushing out the stomach contents, which were collected into sterile bottles. The stomach contents were preserved in 10% formaldehyde and examined in the laboratory under a dissecting microscope.
9. The animals were released back to their original place of capture after measuring and sampling.
10. Data were analysed using the statistical package Minitab for basic statistical analysis, ANOVA and Anderson – Darling normality tests.

Results

During the survey a total of 338 specimens (Males 72 (21.3 %), females 56 (16.6 %), un-sexed 174 (52 %) and un-sexed juveniles 36 (10.7 %) of *Ceratophora tennentii* were observed. Of these, only some were investigated (Tables 1, 2 and 3).

Details of these investigations are listed under the respective subheadings.

Morphometry

A statistical summary of selected morphometric measurements of *Ceratophora tennentii* is presented in Table 1. Anderson – Darling tests indicated all male and females data sets were normally distributed (p values from 0.07 to 0.9) and hence statistical comparisons were made using ANOVA. The results showed that neither total body length, snout vent length nor tail length were significantly different between males and females, ANOVA p values from 0.16 to 86. In some males unusually large leaf like appendage on the snouts were observed. The lengths of the appendage as well as the length of the hemipenis were also recorded in these males.

Pethiyagoda & Manamendra-Arachchi (1998) report the following measurements: a syntype in the British Museum SVL = 88.5. WHT material SVL of males 59.1, 65.9, 64.2, 62.8, and females 71.9, 68.2mm.

Table 1

Measurements of *Ceratophora tennentii*.

(Mean dimensions are shown with standard deviations (SD), minimum (Min) maximum (Max) and sample sizes (N) for each data set)

	Total length					Snout to vent length					Tail length				
	Mean	± SD	Min	Max	N	Mean	± SD	Min	Max	N	Mean	± SD	Min	Max	N
Males	211.8	23.8	176	261	24	74.2	9.0	56	95	24	137.7	16.6	116	172	24
Females	203.6	36.3	155	277	17	74.9	13.8	53	95	17	128.7	23.6	102	185	17
Juveniles	81.8	20.1	66	124	7	31.3	1.9	29	35	7	50.6	18.5	36	89	7

Habitat and distribution

Ceratophora tennentii inhabits moss and lichen-covered tree trunks in the Tropical Montane Wet forests, Wet Sub-Montane evergreen forests and plantations (e.g. cardamom and Pine) from altitudes 760 to 1700 m in the Knuckles Massif (Plate 3 Figures 3 & 4). Of 68 records of *Ceratophora tennentii*: 25 (37%) instances was observed on various trees; 15 (22%) on cardamom stalks; 12 (18%) on the leaf litter on the forest floor; 4 (6%) times on low vegetation; 4(4%) times on rocks and on road and on grass one instances each. The average rainfall in these habitats varies from 2540 to 5080 mm, and the temperature varies according to altitude, but above 1000 m it is usually around 18°C. The forest floor in these habitats has a thick layer of cool moist leaf litter, decaying logs, moss-covered boulders whereas the pine plantations have a thick layer of fallen pine needles. We also observed a wide variety of insects, arthropods, grubs and caterpillars on the forest floor.

However, *C. tennentii* appears well adapted to the cardamom (*Elettaria cardamonium*) plantations as well, where only a few moss and lichen covered trees exist, as the majority of the original trees were removed to grow cardamom. We also observed *Ceratophora tennentii* in Pine plantations that conspicuously lacked the typical moss and lichen covered tree trunks with thick foliage and the moist leaf litter on the forest floor. We

also observed few specimens of *Ceratophora tennentii* in a pine plantation near the forest office at Loolwatte (Deenstone) but not in most other pine plantations investigated (refer de Silva *et al.* 2005b in this volume) (Table 2). This may be due to the pine plantation at Deenstone being surrounded by natural forest, and perhaps the *Ceratophora tennentii* came to this new habitat for foraging and basking.

Ceratophora tennentii were also observed at: Kalduriya, Thangappuwa, Riverston, Rangala, Gammaduwa, Kobonilla, Dotalugala, Deenstone, Corbett's Gap and Horakanda. Pethiyagoda & Manamendra-Arachchi (1998) also found it at Laggala and Midlands.

Microhabitat unitization of *Ceratophora tennentii*

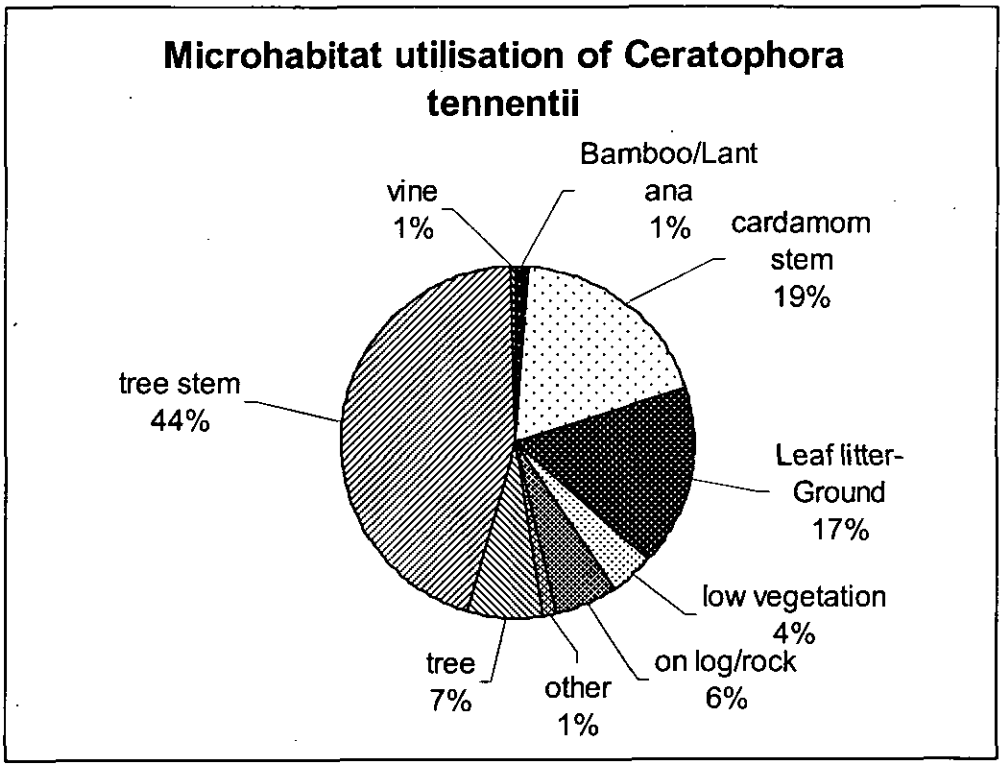


Table 2
***Ceratophora tennentii* observed within the quadrats**

Quadrat No	location	Habitat	Altitude (in meters)	*C. tennentii*
3	Near forest office	Pine	1227	2m 2f (gravid)
13	Near Corbets gap	Cardamom	1250	1m, 2f, 1juven
14	Near Corbets gap	Cardamom	1300	1m, 1f, 1NS
15	Above Kobonila	Disturbed cloud forest		1m, 1J
16	Horakanda	Disturbed cloud forest		1m
19	Rangala	Cardamom	1179	1 ju
20	Above Kobonila	Disturbed cloud forest	1198	2 NS
21	Above Kobonila	Disturbed cloud forest	1230	1f
22	Above Kobonila	Cardamom	1153	1f, 2NS

Behaviour

Ceratophora tennentii is a diurnal, slow-moving, arboreal lizard. It was observed on tree trunks, on cardamom stalks between 0.3 to 1.5 m above ground and on the forest floor. The highest observation was at 4 meters above the ground on a tree trunk. All specimens observed were immobile since darkness and were on the branches of shrubs and cardamom stalks, and the first specimen observed to become active did so at around 06:40 hours (well after dawn). Although *Ceratophora tennentii* is an arboreal lizard, it also spends some time on the forest floor foraging as well as egg-laying. In a sample of 68 specimens 12 (18 %) were observed on the forest floor. Details of thermoregulation behaviour can also be found in de Silva *et al.*, (2005e).

Food

Ceratophora tennentii though a slow moving lizard is an active 'sit and wait' foraging species. Similar observations were made of *Ceratophora stoddartii* at Horton Plains (de Silva, 1999). During the Knuckles survey we observed an individual *Ceratophora tennentii* devouring a large caterpillar on a tree trunk and a cockroach (Plate 3. Figures 5 & 6). Stomach flushes of some revealed ingested arthropods. Feeding on ants, insects and grubs too were observed. An instance of expelling a green moth larva after catching it is reported by Rodrigo and Jayantha (2004).

Reproduction

During the survey the sex of 128 specimens of *Ceratophora tennentii* was determined. There were 72 males and 56 females. There is a healthy population of *Ceratophora tennentii* widely distributed in the Knuckles. Although we did not observe egg laying or eggs of *Ceratophora tennentii*, we observed several late and early gravid females measuring 81 to 85 mm long from snout to vent during the months of June, July and August 2004. Gentle feeling of the stomach of the gravid females indicated the presence of 3 to 5 eggs. Several hatchlings were observed on the forest floor in November 2004 and January 2005. *Ceratophora tennentii* hatchlings resemble *Otocryptis wiegmanni,* as do *Ceratophora stoddartii* hatchlings. The hatchlings are light brown with dark brown markings. They are more terrestrial in habit and merge well with the dry leaves of the forest floor.

Threats

Perhaps the biggest threats faced by *Ceratophora tennentii* are habitat loss, habitat alterations and habitat fragmentation. A major portion of the natural vegetation of the Knuckles Massif was first cleared for coffee (*Coffea arabica*) around 1855. However, with the advent of the coffee rust disease (*Hemeleia vastatrix*) in 1867, the coffee plantations in the island were threatened with extinction. Since then, tea (*Camelia sinensis*) has been grown on a large scale, even in the mountains of the Knuckles and to within a "few hundred feet of the crest" Cooray (1961). More recently, cardamom (*Ellettaria cardamomum*) has been cultivated on a commercial scale since the latter part of the 20th century.

Cardamom is planted under the shade of tall trees, thus most other trees were removed and saplings of forest trees were not allowed to grow, resulting in degradation of natural forest over the years.

Some other threats identified were: Soil erosion, illegal tree felling, decrease of natural habitats, changes to landscape, road kills due to traffic and cannibalism (Plate 3 Figures 7 & 8). Large parts of the forest in the Knuckles are highly fragmented. The animals were earlier illegally collected and exported because of the demands of the exotic pet market. Road kills and mortality from frequent forest fires are major threats at present. In addition, the landscape has been changed by the introduction of alien tree species (such as pines, acacia etc), and there has been an increase in alien invasive weed species (*Lantana* spp.) bamboo *(Indocalmus* spp.). There is also some evidence of the encroachment of *Calotes versicolor,* a known predator of hatchlings of other agamids, into *Ceratophora tennentii* habitat. Application of agrochemicals in home gardens, shifting cultivation and other cultivations just adjoining the Knuckles conservation area was observed in recent times. Since *Ceratophora tennentii* is a montane cloud forest species living in a cool atmosphere it may be sensitive to temperature increases over long periods. A catastrophic mortality of *Cophotis ceylanica* was observed in the Hakgala area that coincided with a rise in the atmospheric temperature (de Silva, 1996; Palihawadana, 1998).

The adaptability of many endemic and relict reptile species to human habitations and man made monoculture plantations is common in Sri Lanka, for example *Lyriocephalus scutatus* in suburban gardens (de Silva, 2001). At Knuckles we observed the abundance of the endemic forest geckos *Geckoella triadrus* and *Cyrtodactylus soba* inside dwellings in and around the Knuckles conservation area (refer de Silva *et al.,* 2005k in this volume). The latter species was observed to be common in many human dwellings at Knuckles. Other examples of reptiles that have adjusted to inhabit man made habitats are *Calotes nigrilabris* at Horton Plains, Nuwara Eliya and Hakgala where many could be seen on the alien invasive plant gorse (*Ulex uropeas*) (de Silva, 1999), and the relict species *Cophotis ceylanica* which inhabit cypress trees and gorse in the Nuwara Eliya and Hakgala areas (de Silva, 2001; Palihawadana, 1998).

Parasites

To understand the status, threats to *Ceratophora tennentii* it is important that we have information on health and disease. For instance, there is always the threat of extinction from disease in endangered species. Thus during the Knuckles expedition careful attention was given to assess the health status of *Ceratophora tennentii.* Hence faecal sample was collected from this agamid from all localities we studied and observed in some Coccidia oocysts (refer de Silva *et al.,* 2005f in this volume). Crusz & Sanmugasunderam (1974) reports trematodes from *Ceratophora tennentii.*

Conservation history

The 7th amendment to the Fauna and Flora Protection Act (No. 49 of 1993) gave total protection to *Ceratophora tennentii.* The Department of Wild Life Conservation is empowered to enforce the provisions to protect this agamid. The Police and Sri Lanka Customs Departments too are empowered by the Fauna & Flora Protection Ordinance to enforce the provisions to protect this agamid. The species is listed in Appendix I of CITES and in Alliance for Zero Extinction profiles.

Recommended Conservation Actions

The conservation measures we propose to save this reptile from extinction are:

1. Identify specific threats faced during each of the phases of its life history – egg, hatchling, juvenile and adult. Effects of human activity on the prey species of this lizard.
2. Linking fragmented forest patches to larger areas by re-planting with native tree species.
3. Studies in other parts of the country as well as at Knuckles have indicated that domestic cats and

poultry feed on agamids. Thus keeping domestic cats and poultry by residents within the Knuckles needs immediate monitoring.

4. Enrichment of natural habitats by removing all buildings within the protected area. Also advocate that hoteliers and residents in the Knuckles to exert minimum impact to the forest.

5. Although it is not critical at present, a captive breeding (in-situ or ex-situ) programme to generate a data base on husbandry techniques should be initiated to be used in the event of future major problems. Assistance to be sought from organizations skilled in this area, for example the Jersey Zoo, United Kingdom and the Lizards Advisory Group in the USA.
6. Conduct awareness programmes for settlers and hoteliers in the Knuckles.

7. Identification of the effects of human activity on the prey species of this lizard.

Acknowledgements
We thank the following: Mr. Sarath Fernando, Conservator General, Forest Department for permission to conduct the study (FRC/5 and FRC/6). Director General, Department of Wildlife Conservation and Mr. H. D. Rathnayake for approvals (WL/3/2/1/14/12). The Forest Department officers at Loolwatte and Illukkumbura for their friendly support throughout the study.

University of Edinburgh, UK for funding and supporting Project Knuckles 2004 Undergraduate Research Expedition. The University of Edinburgh team were funded by the: Aranmore Memorial Traveling Scholarship, Davis Fund, James Rennie Bequest, Student Travel Fund, Weir Fund, William Dickson Traveling Fund, British Student Travel Fund, Edinburgh No 2 Fund, Gilchrist Educational Trust, Lindeth Charitable Trust, Peoples Trust for Endangered Species and a Royal Geographical Society Expedition Research Grant (Gumby Award).

Roger Meek helped with data analysis.

Aaron Bauer was supported by Villanova University and by Grant DEB 0515909 from the National Science Foundation. Global Gecko Association (John Rudge) for sponsoring the gecko stickers.

Literature Cited

Crusz, H. & V. Sanmugasunderam. 1974. Parasites of the relict fauna of Ceylon. iv. Zeylanurotrema lyriocephali gen. et sp. nov. and other trematodes from mountain lizards and a rodent. *Annals de Parasitologie (Paris)*. 48(6): 797-810 (records trematodes from *Ceratophora tennentii, Lyriocephalus scutatus*)

de Silva, Anslem. 1999. *The habitat preferences and the status of amphibians and reptiles at Horton Plains National park.* Zoological Survey of Sri Lanka, National Science Foundation, Colombo. 67 pp.

de Silva, Anslem. 2001. *The Herpetofauna of Sri Lanka: historical aspects and current status.* Ministry of Environment, 100 pp + 150 plates .ISBN 955-96005-0-8

de Silva, Anslem , A. Bauer, C. C. Austin, S. Goonewardene, J. Drake, P. de Silva, M.G.T.H. Aberathna, T. Dassanayaka, G. S. Samarawickrama, R. D. C. S. K. Dasanayaka, A.M.R.K. Amarakoon & M. M. Goonasekera. 2005a. The diversity of the knuckles ecosystem: with special reference to its herpetofauna. *Lyriocephalus* Special issue, 2005 November, Volume 6 Numbers 1 & 2:

de Silva, Anslem, A. Bauer, C. C. Austin, S. Goonewardene, J. Drake, P. de Silva, R.D.C.S.K.Dasanayaka, A. M. R. K. Amarakoon & M. M. Goonasekera. 2005b. Species diversity and richness of the herpetofauna in large leaf litter plots in the Knuckles ecosystem. *Lyriocephalus* Special issue, 2005, Volume 6 Numbers 1 & 2.

de Silva Anslem, R. Meek, A. Bauer, S. Goonewardene, J. Drake, R. D. C. S. K. Dasanayaka, A.M.R.K. Amarakoon & M. M. Goonasekera. *2005e. First studies on the* thermal ecology of *Ceratophora tennentii*: (Sauria: Agamidae) inhabiting the cloud forests of Knuckles Massif, Sri Lanka. *Lyriocephalus* Special issue, 6 (1 & 2): .....

de Silva, Anslem, R. P. V. J. Rajapaksa, R.R.M.K.K. Wijesundera, A. Bauer, S.Goonewardene, J. Drake, M. de Silva and N. A. N. D. Perera. 2005f. Preliminary investigations of the parasites of agamids inhabiting the Knuckles mountain range, with special reference to *Ceratophora tennentii* (Reptilia: Agamidae). *Lyriocephalus* Special issue, 2005, Volume 6 Numbers 1 & 2.

Deraniyagala, P. E. P. 1931. Some Ceylon lizards. *Spolia Zeylanica* 16(2): 139-180.

Deraniyagala, P. E. P. 1953. *A Colored atlas of some vertebrates from Ceylon, Vol.2, Tetrapod reptilia.* Ceylon National Museum, 101 pp.

Palihawadana, A. 1998. An ecological study of *Cophotis ceylanica.* IN: *Biology and Conservation of the Amphibians, reptiles and their habitats in South Asia.* (Ed.) Anslem de Silva, 253-260.

Pethiyagoda, R. & K. Manamendra-Arachchi. 1998. A revision of the endemic Sri Lankan agamid lizard genus *Ceratophora* Gray, 1835, with description of two new species. *J. South Asian Nat. Hist.*, 3(1): 1-50.

Ratnayake, H. D. 2005. Some aspects of the vegetation of the Knuckles ecosystem The Diversity of the Dumbara Mountains (The Knuckles Massif, Sri Lanka): With special reference to its herpetofauna. *Lyriocephalus* Special issue, Volume 6 Numbers 1 & 2:

Rodrigo, R.K. & D. Jayantha. 2004. An observation of the foraging behaviour of *Ceratophora tennentii* Günther, 1861, Knuckles Forest Range in Sri Lanka. *Reptile Rap*, Newsletter of the South Asian Reptile Network, No. 6: pp 11.

Plate 3

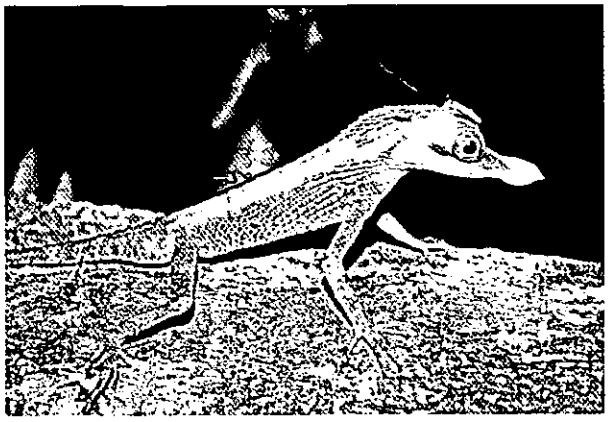


Figure 1. *Ceratophora tennentii* (Photo: R. Gunawardhana)

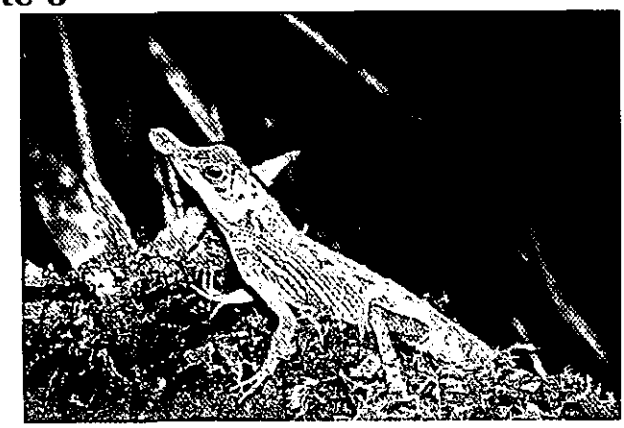


Figure 2. *Ceratophora tennentii* (female)

Figure 3. Wet Sub-Montane evergreen forests

Figure 4. Cardamom plantations

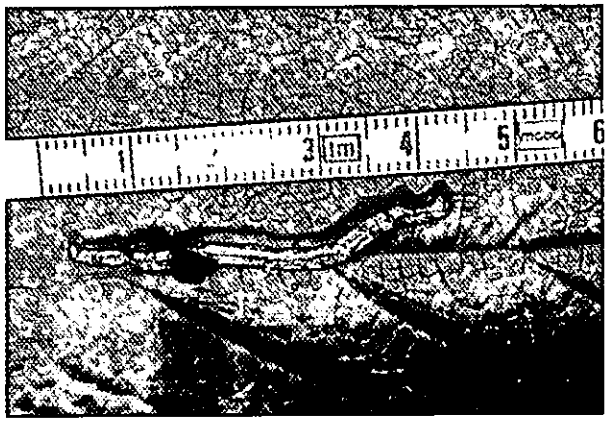


Figure 5. Grub eaten by *tennentii*

Figure 6. *C. tennentii* feeding on a cockroach

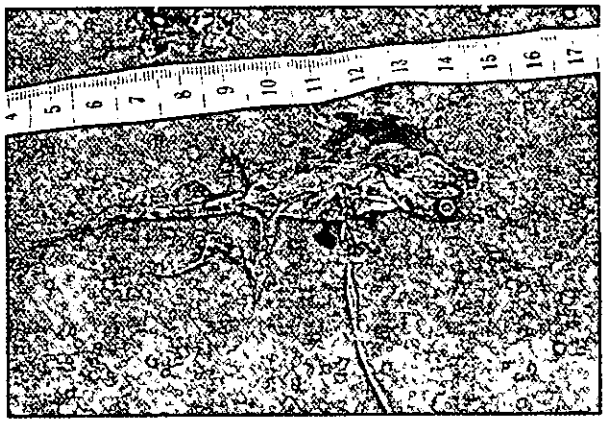


Figure 7. Road kill

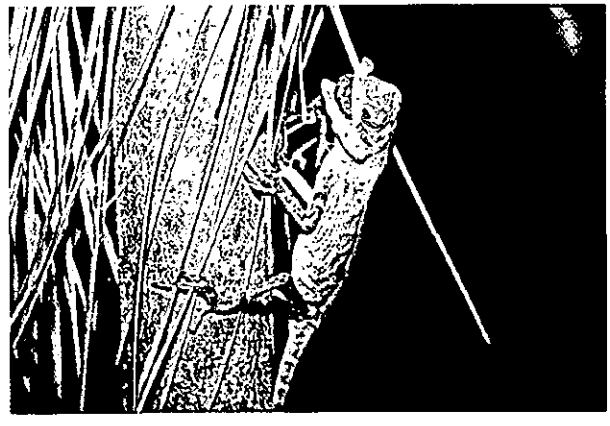


Figure 8. Cannibalism

Photographs: © Suraj Goonewardene and Anslem de Silva

The Diversity of the Dumbara Mountains (The Knuckles Massif, Sri Lanka): With special reference to its herpetofauna.
Lyriocephalus Special issue, 2005 November, Volume 6 Numbers 1 & 2: 65-71
ISSN 1391–0833

FIRST STUDIES ON THE THERMAL ECOLOGY OF *CERATOPHORA TENNENTII*: (SAURIA: AGAMIDAE) INHABITING THE CLOUD FORESTS OF THE KNUCKLES MASSIF, SRI LANKA

Anslem de Silva[1], R. Meek[2], A. Bauer[3], S. Goonewardene[4], J. Drake[4], R.D.C.S.K.Dasanayaka[5], A.M.R.K. Amarakoon[5] & M. M. Goonasekera[5]

[1]15/1 Dolosbage road, Gampola, Sri Lanka. Email: kalds@sltnet.lk
[2] 7 Rue Georges Clemenceau, Chasnais 85400,France. Email Rogermeek85@aol.com [3]Department of Biology, Villanova University, 800 Lancaster Avenue, Villanova, Pennsylvania 19085, USA. Email: aaron.bauer@villanova.edu [4]University of Edinburgh, UK
[5]Dept of Biological Sciences, Rajarata University of Sri Lanka

Keywords: *Ceratophora tennentii,* infra-red Pyrometer, body temperatures, thermoregulation,

Introduction

The leaf nose lizard *Ceratophora tennentii* (Günther and Gray 1861) is a relict agamid inhabiting the Knuckles Massif (Plate 3 Figure 1) and is one of five species of *Ceratophora* found in Sri Lanka (Pethyagoda & Manamendra-Arachchi, 1998). This agamid was first described by Günther and Gray in 1861 in Sir Emerson Tennent's book 'Sketches of the Natural History of Ceylon'. The distribution of the genus in Sri Lanka is of interest as it encompasses the three distinct massifs: the Knuckles, Central and Rakwana mountain ranges. The status of the five species varies; *C. erdeleni* and *C. karu* have only small populations and are known only from a few forests (Morningside Forest Reserve of the Sinharaja World Heritage Site), whereas *C. aspera* and *C. stoddartii* occur in appreciable populations in a wider area - though highly fragmented - throughout. The fifth species, the slow moving *C. tennentii* is known only from the cool mountain forests of the Knuckles Massif (Plate 1 Figure 5). Its natural habitats have been greatly disturbed and altered during past two centuries when extensive clearing of the Knuckles for coffee and tea. Subsequently, the habitat was further disturbed when large commercial scale cultivation of cardamom began since late 1960's. *C. tennentii* is considered an Endangered agamid (IUCN Red Data Book, 2002; De Silva, Molur & Walker, 2000). Animals with limited distributions are often sensitive to changes in habitat structure and it is important that key aspects of *C. tennentii* biology and ecology are known. Thermoregulation is central in this respect, since most physiological processes are temperature dependent (Avery, 1982; Huey, 1982) and may influence habitat selection and adaptation, but the degree to which thermal concerns dominate reptile ecology may differ between species (Gans & Dawson, 1976). Information on thermal ecology is also necessary for habitat management decisions particularly if the species is vulnerable to anthropogenic disturbance. Several studies of thermoregulation of Sri Lankan reptiles have been published but these have dealt mainly with *Varanus salvator* and *V. bengalensis* (Dryden & Wikramanayake, 1991; Dryden, Green, Wikramanayake & Dryden. 1993; Rathnayake *et al.*, 2003; Wikramanayake & Green. 1989; Wikramanayake & Dryden, 1993; Wikramanayake, 1995). The mountain forests of Sri Lanka are similar to the well studied forests of Central and South America in that they present particular problems for thermoregulating reptiles (see

review in Smith and Ballinger, 2001). They often have closed canopy with only limited sunlight penetration and are frequently covered in cloud. Current theory predicts that reptiles living under such conditions will, to some extent, abandon thermoregulation and allow body temperatures to track environmental temperatures (Huey,1982). The reasons for this may vary, but usually concern the distances and time involved in accessing the limited sunlit patches to raise body temperatures; if environmental temperatures are sufficiently high for activity it may be more economical for a reptile to abandon active thermoregulation and track the temperatures in the immediate vicinity. However, such temperatures can be below those required for optimum physiological performance although optimal in an ecological context (Huey, 1982). This paper is the first investigation of the thermoregulatory habits of *C. tennentii* and has been undertaken with the aim of providing a basis for future more in-depth studies.

Methodology

One hundred and sixty-five lizards were captured and immediately measured for body temperatures with minimal handling. Simultaneously, in most instances, associated air (n = 151) and substrate (n = 140) temperatures were recorded.

Substrate temperatures were those at the site of capture of the lizard and were either soil or tree bark temperatures; air temperatures were taken 1.5 m above the ground at the site of capture. The main results presented here are based on cloacal temperatures measured by inserting a digital thermometer (infra-red Pyrometer:130 mm stainless steel sensor probe model ST-9263A/B/C) into the cloaca but in anticipation of future studies skin surface temperatures were also measured using the same infra-red Pyrometer. The pyrometer detects infra-red energy by focusing it onto a germanium filter (emissivity of reptiles = 0.95 (Tracy, 1982)). This instrument has a residual error of $\pm$ 0.1°C but needs to be applied close to the lizard - within approximately 15cm of skin surface, to give an accurate reading.

Four basic types of behaviour were identified and recorded simultaneously with body temperatures. They were defined in the following way: (i) *basking* – located in an area with either full or dappled sunlight with the lizard normally inactive but some postural movement may have been present i.e. opening of the mouth, changing position relative to the sun, feet movement etc; (ii) *shade* – located in an area with no sunlight and basically no movement; often located at the root base or the stem of cardamom or other vegetation; (iii) *active* – involved in some form of locomotory movement; (iv) *feeding* – in the act of securing or consuming prey.

Results

Behaviour

Basking in dappled or sunlit patches accounted for 45.7% of observations. 32.2% of lizards were found in shaded areas on leaf litter on the forest floor or low growing vegetation. Locomotory activity was observed 13.8% of the time and feeding 8.5%.

Body temperatures.

Fig 1 shows box-plots of *C. tennentii* body temperatures (*mean* = 21.8±2.2°C, range = 17 – 30°C, n = 165) with corresponding substrate (*mean* = 19.9±1.7°C) and air temperatures (*mean* = 21.0±2.1°C). Body temperatures were significantly higher than both substrate and air temperatures (substrate, $F_{(1,254)} = 42.03$, $p < 0.0001$; air, $F_{(1,327)} = 8.34$, $p = 0.004$).

Body temperatures (T_b) were plotted against corresponding air (T_a) and substrate temperatures (T_s) in a test for thermoregulation. Corrected r^2 values were calculated to estimate the amount of variation in body temperature that can be explained by variation in air or substrate temperature. This gave, for air temperature, the regression (with standard error):

$$T_b = 2.6+0.91\pm0.04T_a,\ r^2 = 75.4\% \qquad (1)$$

The 0.91 regression coefficient is significantly different from the theoretical value of 0 required for thermoregulation (t = 22.3, p >0.0001) but also from the value of 1 for thermoconformity (t = 2.25, p <0.05). The r^2 value does nevertheless indicate body temperature changes with changing air temperature although this is not necessarily a causal relationship. A plot of air temperature against the differences between air temperature and body temperature (Fig. 2B) suggests that the lizards were elevating body temperatures above air temperatures (*mean difference* =0.8±1.1°C above) irrespective of how high or low air temperatures were.

The regression for substrate temperatures gave:

$$T_b = 1.1+1.02\pm0.1T_a,\ r^2 = 52.3\%$$

The regression coefficient is in good agreement with thermoconformity. However the low r^2 value and the standard error (about 10% compared to that for air temperature of around 4%) indicates that substrate temperatures are a less important influence on body temperatures than air temperatures.

Variance in body and environmental temperatures.

A further test of thermoregulation was made using a comparison of the equality of body and environment temperature variances using an *F*-test. Variance as a method of determining thermoregulatory precision (Huey & Slatkin, 1976) assumes that the lizards were regulating around a mean value and has been the subject of much discussion since there is some evidence that reptiles regulate between lower and upper set points (Berk & Heath, 1975; Barber & Crawford, 1977). Variance in body temperature may, however, provide insight for predicting whether a reptile can achieve greater body temperature precision by restricting activity to microenvironments with limited thermal variance (Hertz & Huey, 1981) or has access to a greater range of thermal resources. The null hypothesis of the *F*-test is that the variances are equal and that the lizards are not attempting to thermoregulate precisely. The results supported the null hypothesis for air temperature (F = 1.09, p = 0.58) but not for substrate temperature F = 1.66, p = 0.008, where body temperatures had significantly greater variance.

Relationship between skin surface and cloacal temperature.

Regression analysis of cloacal temperature (T_b) with skin surface temperature (T_{ss}) gave

$$T_b = -0.71+1.1\pm0.16T_{ss}\ (r^2 = 66.5\%) \qquad (2)$$

This suggests that skin surface temperature gives a reasonable indication of cloacal temperature. The error in the equation is about 14.5% and hence skin surface temperature may be a moderately useful measurement for future studies of continuous observation of individuals, since it is non-invasive and less likely to influence behaviour than cloacal measurement.

Discussion and recommendations

The preliminary results presented here have shown that *C. tennentii* operates at relatively low body temperatures that closely track air temperatures. Basking time appears to explain the approximate 2°C difference that body temperatures were maintained above substrate/ air temperatures. Although the difference was small, it was fairly consistent across the temperature ranges. This is unusual in a species that spends time basking. Most heliothermic lizards, for example, maintain greater differences between body and environmental temperatures at low temperatures, this then becomes progressively smaller as environmental

temperatures increase (Huey, 1982; Avery, 1982).

The majority of basking did occur in dappled sunlight, which is less effective in raising body temperature; seeking out full sunlit patches or increasing basking intensity may be too costly in an ecological context. However, it should be noted that by basking *C. tennentii* differs from many other forest lizards. For example, *Anolis gundlachi* in the forests of Puerto Rico does not bask or regulate its time of activity (Heatwole, *et. al.*, 1969) nor does *Hypsilurus spinipes* in Australian forests (Rummery *et al.*, 1994). Research in natural enclosures on tropical forest species have given similar results - for instance in the giant Solomon Island skink *Corucia zebrata* (Mann and Meek, 2004) but basking and partial basking similar to *C. tennentii* was found in *Physignathus cocincinus* (Meek, 1999).

It is of interest that the body temperatures of *C. tennentii* were significantly lower than body (two-sample $t = 5.78$, $p < 0.0001$, $d.f. = 31$) air ($t = 6.01$, $p = 0.0001$, $d.f. = 23$) and substrate ($t = 5.5$, $p < 0.0001$, $d.f. = 15$) temperatures associated with the sympatric agamid *Calotes liocephalus*. Why do the lizards not select these warmer microhabitats or select higher body temperatures? One possible explanation is inter-specific competition from *C. liocephalus*, perhaps in the form of restricting access to prime basking areas or areas with higher environmental temperatures. Variance in body temperature is also significantly greater in *C. liocephalas* ($F=0.36$, $p<0.0001$), perhaps suggesting less precise thermoregulation. However, this could also indicate access to a larger range of thermal resources (Huey, 1982).

C. liocephalus is usually found higher in the canopy and on tree trunks or branches without cover than *C. tennentii* and it may be that here air temperatures and availability of sunlit patches are greater. These results suggest that the Knuckles forest, with limited basking areas, could intensify competition for thermal resources. Competition of this kind has been found in *Anolis* lizards. For instance, species that occur on islands without congeners are active over broader temperature ranges than those in complex anole communities (Ruibal and Philibosian, 1970; Huey and Webster, 1975) although this may not always be the case (Hertz, 1980).

Several studies have assessed the impact of habitat change on the thermal biology of lizard populations (See Smith and Ballinger, 2001 for review). Although it was found, for example, that timber management practices altered the thermal characteristics of habitats thus favouring heliothermic species in some instances (Vitt et al., 1998; Klingenbock et al., 2000), this may not always be the case (Vitt et al., 1998). In non-basking species, particularly those that operate at low body temperatures, excessively hot habitats may exceed temperatures for physiological thresholds. This could influence activity times, metabolic rates and reproduction amongst other things. With the decline of *C. tennentii* in previously occupied habitats as a consequence of anthropogenic activities, this suggests that new detailed research on the species ecology should be given priority.

Acknowledgements

We wish to thank: Mr. Sarath Fernando, Director General, Forest Department for permission granted to (to AdS, AB and CA) (FRC/5 and FRC/6) to conduct the above study. Director General, Department of Wildlife Conservation, Director General, Department of Wildlife Conservation for approvals (WL/3/2/1/14/12). The Forest Department officers at Loolwatte and Illukumbura for their friendly support throughout the study. University of Edinburgh, UK for the approval given (to University of Edinburgh students) and the generous grants: Royal Geographical Society of UK,

We also thank Dr Roger Avery for a critical review of the manuscript.

Literature cited

AVERY, R. A. 1982. Field studies of body temperatures and thermoregulation. In: *Biology of the Reptilia* 12, Physiology C; Physiological Ecology p. 93 – 166. Gans, C. & Pough, F.H. Eds, London: Academic Press.

BARBER, B.J. & E. C. CRAWFORD.1977. A stochastic dual-limit hypothesis for behavioural thermoregulation in lizards. *Physiol. Zool.* 50, 53 – 60.

BERK, M.L. & J.E. HEATH. 1975. An analysis of behavioural thermoregulation in the lizard *Dipsosaurus dorsalis. J. Therm. Biol.* 1,15 – 22.

DE SILVA, ANSLEM., S. MOLUR & S. WALKER. 2000. *Conservation Assesment and Management Plan CAMP Report for amphibians and selected taxa of reptiles of Sri Lanka.* Conservation Breeding Specialist Group, Sri Lanka. 226 pp.

DE SILVA, ANSLEM., C. C. AUSTIN, A. BAUER, S. GOONEWARDENE, Z. HAWKE, V. VANNECK, A. DRION, & M. M. GOONASEKERA. 2004. Some behavioral aspects of *Ophisops leschenaultii lankae* (Reptilia: Lacertidae) at Nilgala fire-savannah, Sri Lanka.2004. *Lyriocephalus* Special Issue, 2004, Vol. 5, Nos. 1 & 2: 206 - 212.

DRYDEN, G. L. & E. D. WIKRAMANAYAKE. 1991. Space and time sharing by *Varanus salvator* and *Varanus bengalensis* in Sri Lanka. In: *Advances in monitor research.* Ed: W. Bohme and Hans-Georg Horn. Mertensiella. (Supplement Salamandra). 2: 111-119.

DRYDEN, G. L., B. F. GREEN, E. D. WIKRAMANAYAKE & K. G. DRYDEN. 1993. Thermal ecology of habitat and microhabitat use by sympatric *Varanus bengalensis* and *V salvator* in Sri Lanka. *Copeia* 3: 709-714

GANS, C AND W.R. DAWSON. 1976. Reptilian physiology: an overview. In: *Biology of the Reptilia* 5,(1),1 – 17. (Gans, C. & Dawson. Eds). London: Academic Press.

HEATWOLE, H., T.H. LIN, E. VILLALON, A. MUNIZ, AND A. MATTA. 1969. Some aspects of the thermal ecology of Puerto Rican anoline lizards. *J. Herpetol.* 3, 65 – 77.

HERTZ, P.E AND R.B. HUEY. 1981. Compensation for altitude changes in the thermal environment by some *Anolis* lizards on Hispaniola. *Ecology* 62, 515 – 521.

HERTZ, P.E. 1980. Comparative physiological ecology of the sibling species *Anolis cybotes* and *A. maracanoi. J. Herpetology* **14**, 92-95.

HUEY, R.B. 1982. Temperature, physiology and the ecology of reptiles. In: *Biology of the Reptilia* 12, Physiology C; Physiological Ecology 25 – 91. Gans, C & Pough, F.H. (Eds). Academic Press, London.

HUEY, R.B. & M. SLATKIN. 1976. Costs and benefits of lizard thermoregulation. *Q. Rev. Biol.* 51: 363 - 384.

HUEY, R.B. & T. P. WEBSTER. 1975. Thermal biology of a solitary lizard : *Anolis marmoratus* on Guadeloupe, Lesser Antiles. *Ecology* 56, 445 – 452.

IUCN. 1990. 1990 IUCN Red List of threatened animals. IUCN, Gland Switzerland and Cambridge, UK. 288 pp.

KLINGENBOCK, A., K. OSTERWALDER AND R. SHINE. 2000. Habitat use and thermal Biology of the ``land mullet`` *Egernia major*, a large Scincid from the remnant rain forest in southeastern Australia. *Copeia* 2000: 931 – 939.

MANN, S.L. AND R. MEEK. 2004. Understanding the relationship between body temperature and activity patterns in the giant Solomon Island skink, *Corucia zebrata*, as a contribution to the effectiveness of captive breeding programmes. *Applied Herpetology* 1: 287 – 298.

MEEK, R. 1999. Thermoregulation and activity patterns in captive water dragons, *Physignathus cocincinnus*, in a naturalistic environment. *Herpetol. J.* 9, 137 – 146.

PETHIYAGODA, R. & K. MANAMENDRA-ARACHCHI. 1998. A revision of the endemic Sri Lankan agamid lizard genus *Ceratophora* Gray, 1835, with description of two new species. *J. South Asian Nat. Hist.*, 3(1): 1-50.

RATHNAYAKE, N. D., N. HERATH, K. K. HEWAMATHEAS & S. JAYALTH. 2003. The thermal behaviour, diurnal activity pattern and body temperature of *Varanus salvator* in central Sri Lanka. *Hamadryad*, 27(2): 179 – 184.

RUIBAL, R. AND R. PHILIBOSIAN. 1970. Eurythermy and niche expansion in lizards. *Copiea* 1970, 645 – 653.

RUMMMERY, C., C.R. SHINE, D.C. HOUSTEN, AND M.B. THOMPSON. 1994. Thermal biology of the Australian forest dragon, *Hypsilurus spinipes* (Agamidae). *Copeia* 1995: 818 – 827.

SMITH, G.R. AND R.E. BALLINGER. 2001. The ecological consequences of habitat and microhabitat use in lizards: a review. *Contemporary Herpetology* 3: 1 –23.

TENNENT, J. E. 1861. *Sketches of the Natural History of Ceylon with Narratives and Anecdotes Illustrative of the Habits and Instincts of the Mammalia, Birds, Reptiles, Fishes, Insects, &c. Including a Monograph of the Elephant and a Description of the Modes of Capturing and Training It.* Longman, Green, Longman, and Roberts. London. xxiv + 500 pp., 11 pls.

TRACY, C.R. (1982). Biophysical modeling in reptilian physiology and ecology. In: *Biology of the Reptilia* 12, Physiology C; Physiological Ecology 275 – 321. Gans, C & Pough, F.H. (Eds). Academic Press, London.

VITT, L.J., J.P. CALDWELL AND V.R.L.OLIVEIRA. 1998. The impact of individual tree harvesting on the thermal environments of lizards in Amazonian rain forest. *Conservation Biology* 12: 654 – 664.

WIKRAMANAYAKE, E. D. 1995. Activity and Thermal ecophysiology of two sympatric monitor lizards in Sri Lanka.*J South Asian Natural History* 1(2): 213-224.

WIKRAMANAYAKE, E. D. & G. L. DRYDEN. 1993. Thermal ecology of habitat and microhabitat use by sympatric *Varanus bengalensis* and *V. salvator* in Sri Lanka. *Copeia* 1993 (3): 709-714.

WIKRAMANAYAKE, E. D. & B. F. GREEN. 1989. Thermoregulatory influences on the ecology of two sympatric Varanids in Sri Lanka. *Biotropica* 21(1): 74-79.

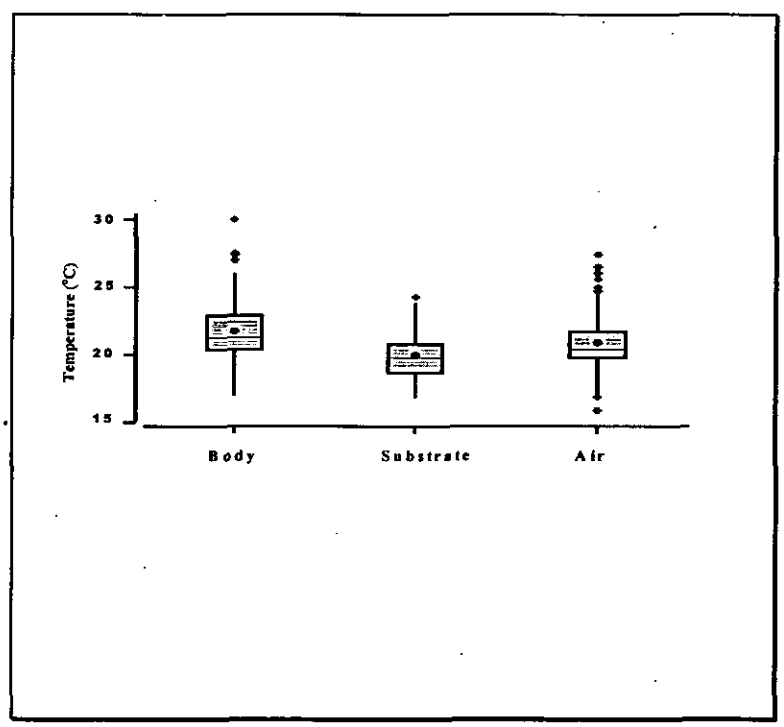


Figure.1. Box plots of *C. tennentti* body temperatures shown with substrate and air temperatures. The boxes represent the interquartile ranges with the means shown as solid circles and medians as horizontal bars. The vertical lines either side of the interquartile ranges represent the general ranges of the data. Diamonds indicate outliers – data that are between 1.5 to 3 times from the interquartile ranges.

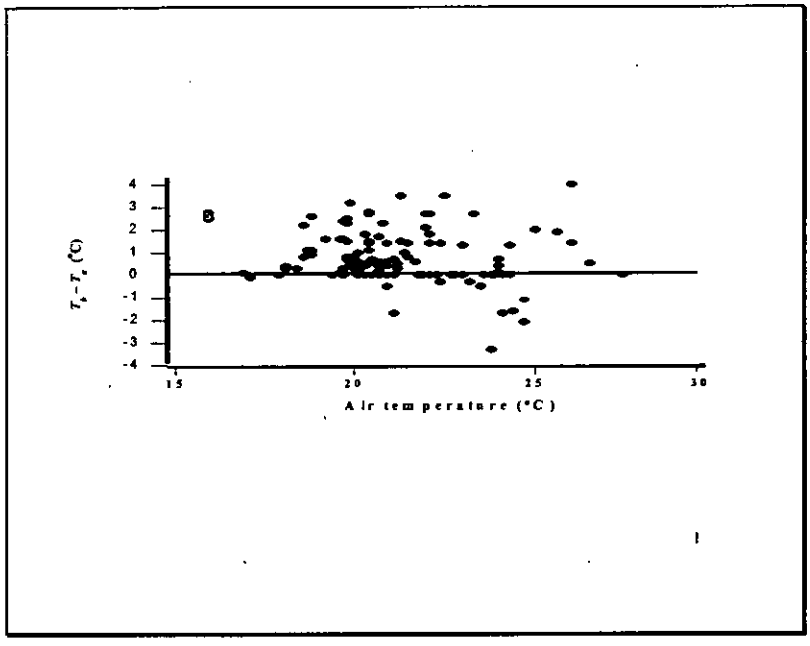


Figure 2. Graph showing the differences between body temperature and air temperature (*Tb* – *Ta*). This shows that most body temperatures were above air temperatures (see text for further information).

The Diversity of Dumbara Mountains (Knuckles Massif, Sri Lanka): With special reference to its herpetofauna. *Lyriocephalus* Special issue. 2005 November, Volume 6 Numbers 1 & 2: 73-76
ISSN 1391–0833

PRELIMINARY INVESTIGATIONS OF THE PARASITES OF AGAMIDS INHABITING THE KNUCKLES MOUNTAIN RANGE, WITH SPECIAL REFERENCE TO *CERATOPHORA TENNENTII* (REPTILIA: AGAMIDAE).

Anslem de Silva[1], R. P. V. J. Rajapaksa[2], R.R.M.K.K. Wijesundera[2], A. Bauer[3], S.Goonewardene[4], J. Drake[4], M. de Silva[2] and N. A. N. D. Perera[2],

[1] *15/1 Dolosbage road, Gampola, Sri Lanka. Email: kalds@sltnet.lk*
[2] *Faculty of Veterinary Medicine, University of Peradeniya, Sri Lanka. jayanthar@pdn.ac.lk*
[3] *Department of Biology, Villanova University, 800 Lancaster Avenue, Villanova, Pennsylvania 19085, USA. Email: aaron.bauer@villanova.edu*
[4] *97, Battersea Park Road, London, SW9 4DU, UK. E-mail: hsr.wild@gmail.com (University of Edinburgh, UK)*
[4] *Creagard, Isle of Mull, PA75 6RA, UK. E-mail: jfdrake@gmail.com (University of Edinburgh, UK)*

Keywords: *Ceratophora tennentii, Cophotis ceylanica,* parasites, coccidian oocysts, Knuckles.

Introduction

Ten species of agamids inhabit the Knuckles mountain range. Of these, seven (70%) species are endemic (refer de Silva *et al.*, 2005 in this volume). The leaf horn lizard (*Ceratophora tennentii*) is the dominant agamid inhabiting the Knuckles Massif. It is common and healthy populations could be observed in many parts of the massif. Detailed accounts of its ecology and thermoregulatory habits are discussed in the present volume (de Silva *et al.*, 2005d; de Silva *et al.*, 2005e). However, due to its restriction to the Knuckles ecosystem and the vast clearing of its natural habitats for coffee, tea and subsequently for cardamom cultivation, it was considered a threatened agamid and was the first agamid to be listed in the IUCN Red Data Book as a threatened reptile from Sri Lanka. Thus, it is of vital importance to understand the threats and health status (internal and external parasites) and diseases of this animal. Thus during the Knuckles Expedition 2004 and 2005 careful attention was given to assessing the health status of *Ceratophora tennentii.* This communication deals with preliminary aspects of parasitic infections observed in C. tennentii and other agamids (*Calotes calotes, Calotes liocephalus, Calotes liolepis, Cophotis ceylanica* and *Lyriocephalus scutatus*) inhabiting the Knuckles ecosystem.

Field methods

The study was conducted from 25th June, 2004 to 20th August 2004 and 14th July to 21st September 2005.

1. Four main survey techniques used were: visual encounter survey (VES), patch sampling, canopy sampling and sampling in large (20 x 20 m) leaf litter quadrats in different vegetation habitats.

2. Animals were captured gently by hand and, with minimal handling. Immediately after taking the cloacal temperature, a faecal sample was collected by gently pressing the abdomen of the reptile. Invariably freshly captured specimens defecate without much effort at the time of capture. As the stools emerged from the cloaca, a numbered, sterile plastic ampule containing a 10% formaldehyde solution was held near the cloaca to collect the faecal sample directly. The stool samples were taken to the Parasitology research laboratory of the Department of Veterinary Pathobiology, Faculty of Veterinary Medicine and Animal Science, University of Peradeniya, for investigations and for deposition for any future work.

3. The animals were released back to their original place of capture after relevant notes were recorded.

Laboratory analysis

In the laboratory, the formaldehyde solution in the faecal sample containers was tipped off and the faecal sample was rinsed several times with saline. Subsequently, the faecal sample was placed in a 1.5 ml micro-centrifuge tube and centrifuged at 1000 rpm for 5 minutes. Finally, the faecal pellet was re-suspended with 100 μl of normal saline. Thereafter, a 25 μl aliquot of the sediment (suspension) was used to prepare a smear on a glass slide. The smear was covered with a cover slip, and observed under a light microscope for parasitic stages, eggs and protozoan oocysts. The macroscopic examination was repeated three times using 25 μl aliquots of each sample. The helminth eggs were examined using a research microscope under 20 and 40 X magnification. Protozoan oocysts were examined to study their morphology under 40 X and 100 X magnification. Drawings of each parasitic stage were executed using a Camera Lucida and all measurements were taken using a micrometer. Sizes of ten samples from each specimen were measured and mean values were taken from the analysis.

Results

The results of the laboratory findings are given in table 2 and Plate 4 Figures 1-4.

Table 2

Parasitic infection observed in agamids with special reference to *C. tennentii* inhabiting the Knuckles

(Knuckles Expedition, 2004, 2005)

Locality	Species	Parasite
	C. tennentii (male)	- none
Riverston	*C. tennentii* (female)	- none
	C. tennentii (female)	Coccidia oocyst with 2 sporosites
Riverston	*C. tennentii* (male)	Coccidia oocyst
	C. tennentii (male)	- none
	C. tennentii (male)	Coccidia oocyst
	C. tennentii (male)	- none
Riverston	*C. tennentii* (female)	- none
	C. tennentii (male)	- none
	C. calotes	- none
Pine (FO)	*C. tennentii* (male)	- none
Corbett's Gap	*C. tennentii*	- none
Kenagommana	*C. liolepis* (male)	- none
	C. tennentii	- none
Corbett's Gap	*C. tennentii* (male)	- none
Rangala	*C liocephalus* (female)	- none
Rangala	*C. tennentii* (male)	- none
Dotalugala	*Cophotis ceylanica*	Nematode larva
Gammaduwa	*C. calotes* (female)	- none
Loolwatte	*C. calotes* (female)	- none
Mon. forest	*L scutatus* (male)	- none
Kobonila	*C. liolepis* (female)	- none
Corbett's Gap	*C. liocephalus* (male)	- none
Kobonila	*C. calotes* (female)	- none
Kobonila	*C. tennentii* (male)	- none
Kobonila	*C. tennentii* (female)	- none
Kobonila	*C. calotes* (male)	- none
Kobonila	*C. tennentii*	- none
Kobonila	*C. tennentii* (male)	- none
Kobonila	*C. tennentii*	- none

Discussion

Laboratory investigations showed that the guts of 13% of agamid specimens investigated were infected with one or more parasites. However, coccidial infection was more prevalent (10%) when compared to nematode infection. We also observed nematode larva from *Cophotis ceylanica* (Pygmy lizard) collected from Dotalugala mountain. However, when compared to our previous study in the Nilgala Fire Savannah (de Silva *et al.*, 2004) the level of parasitic infection in the Knuckles was less. This could possibly be due to climatic differences of the two places. It is known that environmental condition is a major epidemiological factor involving the survivorship of parasites (Soulsby 1982).

Stool samples investigated for parasites from *Calotes calotes* (Green garden lizard), *Calotes liocephalus* (Crestless lizard), *Calotes liolepis* (Whistling lizard), and *Lyriocephalus scutatus* (Lyre head lizard) were negative. However, we observed coccidian oocysts in stool samples from *Ceratophora tennentii*. Though we collected faecal samples from *Ceratophora tennentii* from many localities, only a few stool samples from Riverston contained coccidian oocysts. Two species of nematodes, *Cosmocercoides rickae* and *Meteterakis baylisi*, have previously been recorded from *C. tennentii* (Ogden, 1966) and a wide range of nematodes have previously been recorded from the other species investigated: *Calotes calotes* (von Linstow, 1904), *Cophotis ceylanica* (Baylis, 1935), and *Lyriocephalus scutatus* (Baylis, 1935; Crusz & Sanmugasunderam, 1973; Crusz & Ching, 1975). Crusz & Sanmugasunderam (1974) in their survey of parasites of the relict fauna of Sri Lanka reported a new trematode *Zeylanurotrema lyriocephali* from a *Ceratophora tennentii* collected in Gammaduwa, but we found no evidence of this parasite in our samples.

Acknowledgements

We wish to thank: Mr. Sarath Fernando, Director General, Forest Department for permission granted to (AdS, AB and CA) (FRC/5 and FRC/6) to conduct the above study. Director General, Department of Wildlife Conservation, Mr. H. D. Rathnayake for approvals (WL/3/2/1/14/12). The Forest Department officers at Loolwatte and Illukumbura for their friendly support throughout the study.

University of Edinburgh, UK for funding and supporting Project Knuckles 2004 undergraduate research expedition (special thanks the following University of Edinburgh Funds: Aranmore Memorial Travelling Scholarship, Davis Fund, James Rennie Bequest, Student Travel Fund, Weir Fund, William Dickson Traveling Fund and also British Student Travel Fund, Edinburgh No 2 Fund, Gilchrist Educational Trust, Lindeth Charitable Trust, Peoples Trust for Endangered Species, Royal Geographical Society Expedition Research Grant (Gumby Award). BP (British Petroleum) for the generous grant. Also thanks to Alasdair Ford, Andrew Burns, Douglas Fraser, Laura Packham and Polly Bramham from Project Knuckles 2004 for helping to gather data in the field.

Aaron Bauer was supported by funds from the Department of Biology at Villanova University. USA.

Literature cited

Baylis, H.A. 1935. Two new parasitic nematodes from Ceylon. *Annals and Magazine of Natural History* (10) 16: 187-192.

Crusz, H. & C.C. Ching. 1975. Parasites of the relict fauna of Ceylon. VI. More new helminths from amphibians and reptiles, with a new host-record and redescription of *Acantbocephalus serendibensis* Crusz and Mills, 1970. *Annales de Parasitologie (Paris)* 50(5): 531-558.

Crusz, H. & V. Sanmugasunderam. 1974. Parasites of the relict fauna of Ceylon. iv. *Zeylanurotrema lyriocephali* gen. et sp. nov. and other trematodes from mountain lizards and a rodent. *Annals de Parasitologie (Paris).* 48(6): 797-810

de Silva, Anslem. R.P.V.J.Rajapakse, A. M. Bauer, C. C. Austin, S. Goonawardena, W. M. J. de Silva, Z. Hawke, V. Vanneck, A. Drion & M.

M. Goonasekera. 2004. First report of parasites of *Hemidactylus maculatus hunae* & *Calodactylodes illingworthorum* (reptilia: Geckonidae) inhabiting the Nilgala fire savannah, Sri Lanka. *The Herpetology of Sri Lanka: current research* (Including the Proceedings of the Fourth World Congress of Herpetology, December 2001 and Nilgala Expedition Report, *Lyriocephalus* special edition. Volume 5 (1 & 2): 199 – 205.

de Silva, Anslem., S. Goonewardene, A. M. Bauer and J. Drake. 2005d. *Ceratophora tennentii* Günther & Gray, in Tennent, 1861 (Reptilia: Agamidae) some notes on its ecology. *Lyriocephalus* Special issue, Volume 6 Numbers 1 & 2:

de Silva, Anslem., R. Meek, A. Bauer, S. Goonewardene, J. Drake, R.D.C.S.K.Dasanayaka, A.M.R.K. Amarakoon & M. M. Goonasekera. 2005e. First studies on the thermal ecology of *Ceratophora tennentii*: (Sauria: Agamidae) inhabiting the cloud forests of the Knuckles massif, Sri Lanka. *Lyriocephalus* Special issue, Volume 6 Numbers 1 & 2:

Ogden, C. G. 1966. On some parasitic nematodes from reptiles, mainly from Ceylon. *Journal of Helminthology* 40(1/2): 81-90.

Soulsby, E.J.L.1982. *Helminths, Arthropods and Protozoa of Domestic Animals* (7th Edition). Baillere Tindall, UK

von Linstow, O. 1904. Nematoda in the collection of the Colombo Museum. *Spolia Zeylanica* 1(4): 91-104, pls. i-ii.

Plate 4

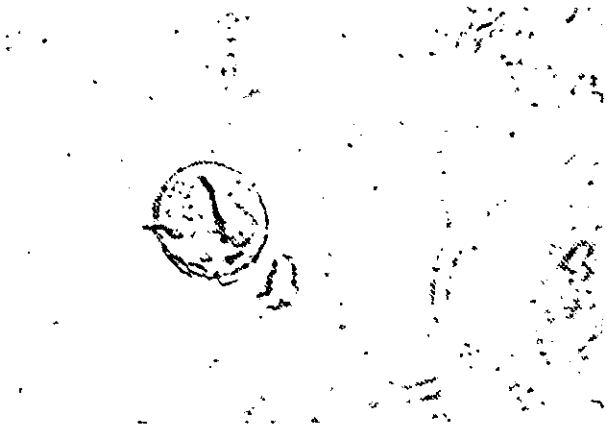


Figure 1. *Hymenolepis* egg

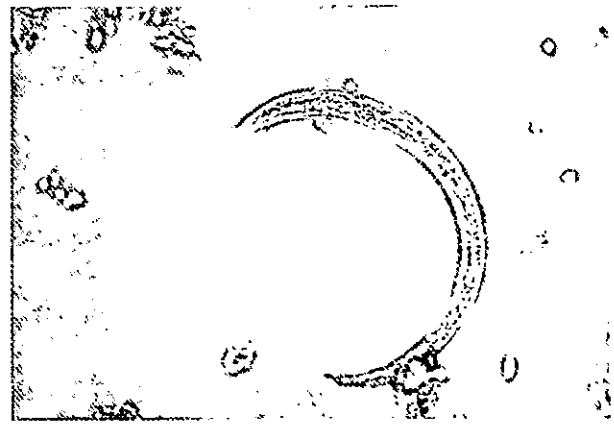


Figure 2. Nematode larvae

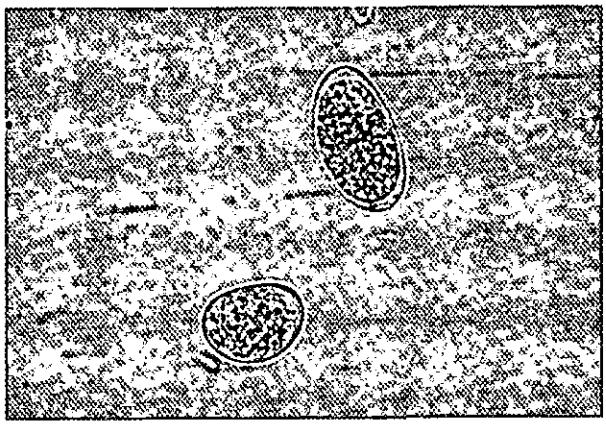


Figure 3. *Spirometra* eggs

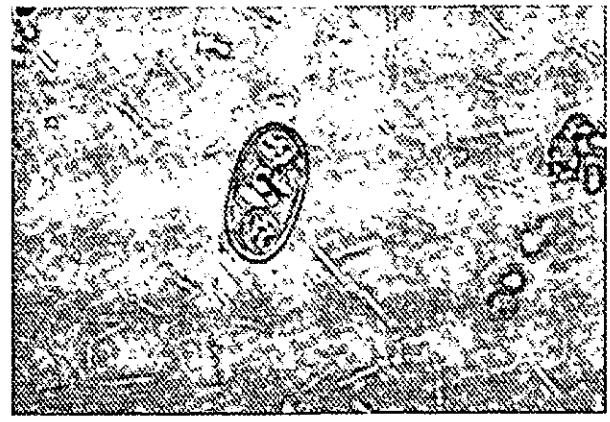


Figure 4. Sporulated Oocyst with sporozoites

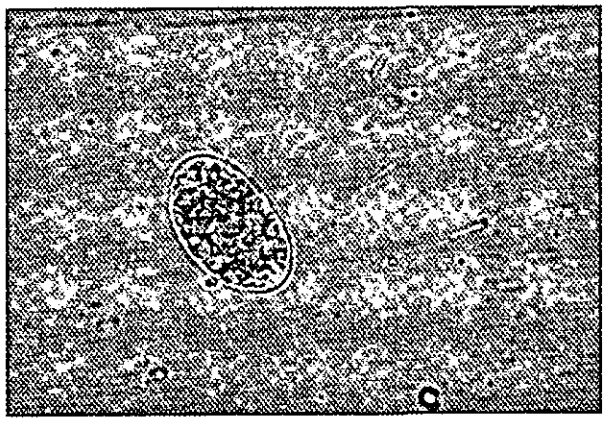


Figure 5. *Spirometra* egg

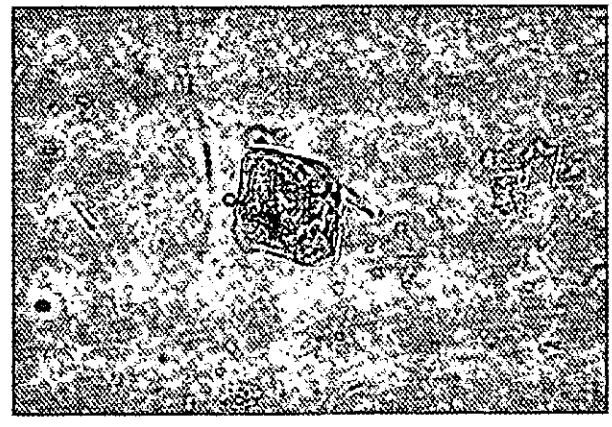


Figure 6. Anoplocephala egg

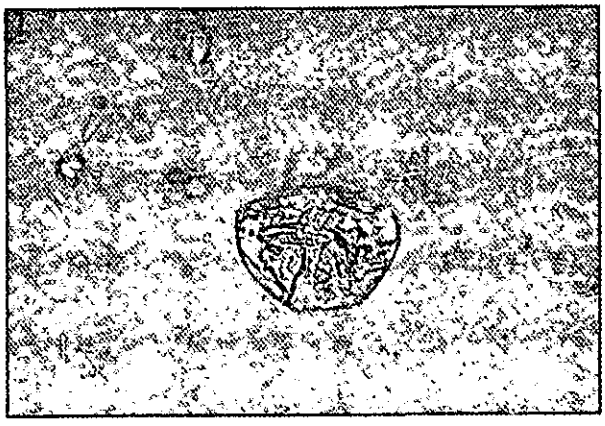


Figure 7. *Hymenolepis*

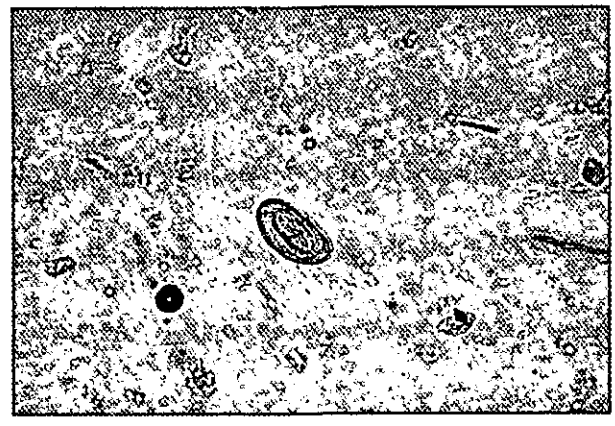


Figure 8. *Sphaerechinorhynchus*

Photographs: Dhammika Perera

The Diversity of Dumbara Mountains (Knuckles Massif, Sri Lanka): With special reference to its herpetofauna. *Lyriocephalus* Special issue, November, 2005 Volume 6 Numbers 1 & 2: 79
ISSN 1391–0833

SHORT COMMUNICATION

INSECT ATTACKING AN *OTOCRYPTIS WIEGMANNI* (REPTILIA: AGAMIDAE)

Anslem de Silva[1] and Suraj Goonewardene[2]
[1] 15/1 Dolosbage road, Gampola, Sri Lanka. Email: kalds@sltnet.lk
[2]97, Battersea Park Road, London, SW9 4DU, UK. E-mail: hsr.wild@gmail.com (University of Edinburgh, UK)

The genus *Otocryptis* is represented by two species: *wiegmanni* (Wagler, 1830) and *Otocryptis nigristigma* Bahir & Silva, 2005. They are small slender agamids, with adults reaching a length of 275 mm (80 mm SVL).

Although *Otocryptis* is mainly a ground dwelling form it may occasionally be seen climbing shrubs, trees and boulders. Furthermore, at night they climb into small shrubs where they sleep at the periphery of branches. *Otocryptis wiegmanni*, an endemic reptile which is of Lower Risk – (near threatened) according to the IUCN Red List criteria (de Silva *et al.*, 2000).

During the Knuckles Expedition, whilst in a tea plantation at Elkaduwa we observed an *Otocryptis wiegmanni* subadult female struggling around noon. Closer examination revealed that an insect was biting the lizard and was attached to its neck (Plate 5. Figure 1). After the insect was removed, the lizard did not show any sings of discomfort and simply ran in the foliage.

A similar phenomenon of a glow worm was observed at Horton Plains National Park feeding on a dead *Cophotis ceylanica* which had possibly been killed by the glow worm (de Silva 1999).

Acknowledgement
A. J. G. Burns, Project Knuckles, 2004 for the photograph.

Literature cited

De Silva, Anslem. 1999. *The Habitat preferences and the status of amphibians and reptiles at Horton Plains National Park.* Zoological Survey of Sri Lanka, National Science Foundation. 67 pages.

De Silva, Anslem., S. Molur & S. Walker. 2000. *Conservation Assessment and Management Plan CAMP Report for amphibians and selected taxa of reptiles of Sri Lanka*. Conservation Breeding Specialist Group, Sri Lanka. 226 pp.

Plate 5

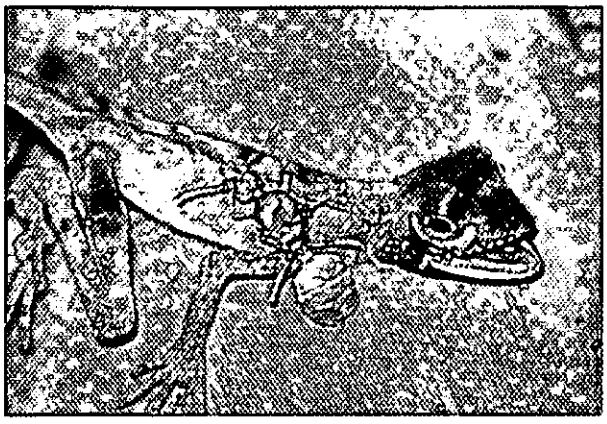


Figure 1. Insect biting *O. wiegmanni*

Figure 2. Pitawala Pathana (Photo: Meek)

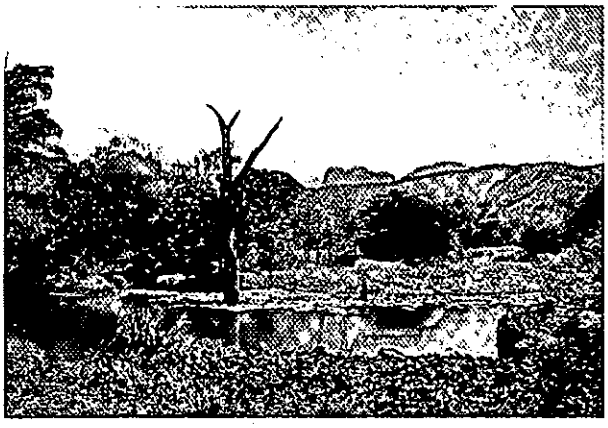


Figure. 3. Hettipola (Wilgamuwa) (Photo: Meek)

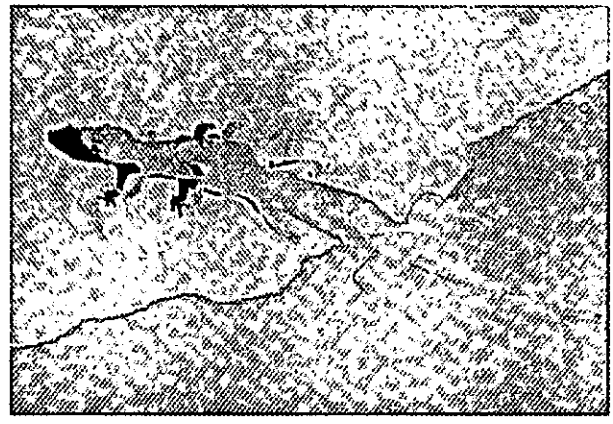


Figure 4. Cannibalism in *Hemidactylus brookii*

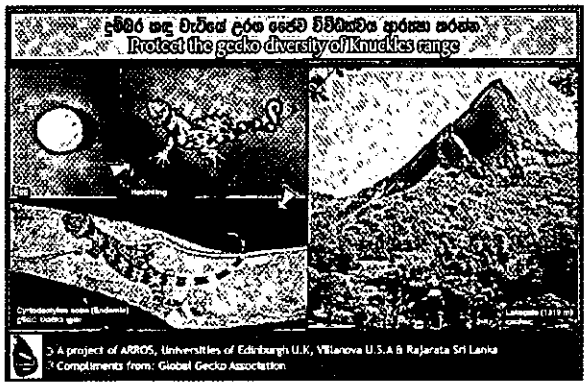


Figure 5. Sticker depicting *Cyrtodactylus soba*

Figure 6. Sticker depicting *Geckoella triedrus*

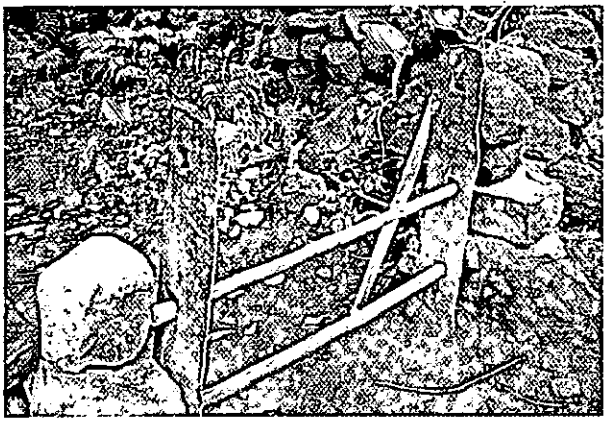


Figure 7. Traditional gate and stonewalls at Mimure

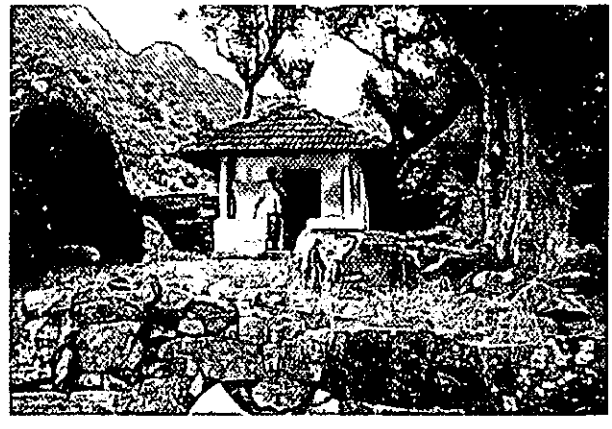


Figure 8. Mimure village temple

Photographs: © Suraj Goonewardene and Anslem de Silva

The Diversity of the Dumbara Mountains (The Knuckles Massif, Sri Lanka): With special reference to its herpetofauna.
Lyriocephalus Special issue, 2005 November, Volume 6 Numbers 1 & 2: 83-93
ISSN 1391–0833

ALTITUDINAL DIFFERENCES IN THERMOREGULATORY BEHAVIOUR IN *CALOTES VERSICOLOR* IN THE KNUCKLES REGION, SRI LANKA.

R. Meek[1], E. Jolley[2], Anslem de Silva[3], S. Goonewardene[4] , J. Drake[4] H.M.N. Chalalochani[5], P.L.C.L.Liyanage[5], T.S. Abeysekera[5], M.D.I.P.K.Mayadunna[5], S.A.U.S. Somathilaka[5] & W.P.R. Chandrarathna[5]

[1]7 Rue Georges Clemenceau, Chasnais, France. Email:Rogermeek85@aol.com
[2]16 Mountfields, Halifax, West Yorkshire, United Kingdom. Email:ediejolley@yahoo.co.uk
[3]15/1 Dolosbage road, Gampola, Sri Lanka. Email: kalds@sltnet.lk
[4]97, Battersea Park Road, London, SW9 4DU, UK. E-mail: hsr.wild@gmail.com (University of Edinburgh, UK)
[4]Creagard, Isle of Mull, PA75 6RA, UK. E-mail: jfdrake@gmail.com (University of Edinburgh, UK)
[5]Dept. of Zoology, Faculty of Science, Rajarata University of Sri Lanka.

Key Words: Operative temperatures, thermoregulatory behaviour, altitude, Knuckles, *Calotes versicolor*

Abstract

Observations have been made on the thermoregulatory behaviour of the agamid lizard *Calotes versicolor* at two different altitudes. Operative temperatures and lizard body temperatures were significantly higher at low altitude (91 metres). The high altitude climate (920+ metres) imposed a behavioural cost for raising body temperature by increased basking. High operative temperatures at low altitude set a premium on shade seeking. Precision of body temperatures, defined as a function of body temperature variance, was not significantly different between populations. Tentative mathematical models for a series of *Calotes* and other squamates, indicated that altitude generally has an influence on body temperatures.

Introduction

The physiological processes in reptiles are largely temperature dependent and temperature influences many functions, for example growth, reproduction, muscular energy and oxygen consumption. Heat is therefore a key environmental resource (Magnusson *et al.*, 1979), although there may be limitations on the ability of reptiles to harness thermal energy, particularly in extreme environments. Early studies indicated that reptiles are able to elevate body temperatures even at high altitudes (e.g.Strelnikov, 1944; Pearson, 1954). However more recent studies have shown there are associated costs involved including, among others, costs in time, behaviour, target body temperatures and behaviour (see Huey,1982 for review). The theoretical model of reptile thermoregulation predicts that if a thermoregulator is faced by a cooler environment than its preferred temperature, it will compensate by adjusting behaviour, for example by increasing basking intensity (Huey and Slatkin, 1976; Huey, 1982). Although this may not always be the case, (e.g. Meek, 1988; Spencer and Grimmond, 1994) much of the evidence supports the theory. Generally, the costs will be to increase basking intensity and/or lower thermal set points and precision of thermoregulation (Huey, 1982). The thermoregulatory response to a particular environment is dependent on the environment in question. For example, Shine and Madsen (1996) suggested that in tropical regions reptile behaviour might only be affected in a minor way by thermoregulatory concerns. Luiselli and Akani (2002) argued that although the importance of thermoregulation in the tropics may not be critical, it nevertheless exists and has ecological consequences.

Most comparative studies have examined climatic effects on thermoregulatory behaviour in temperate reptiles including species from different altitudes (e.g. Brown and Weatherhead, 2000;Bluin-Demers and Weatherhead, 2001; Gvodzik, 2002; Bauwens, *et al.*, 1990). Rather less information is available about the effects of altitude on reptile thermoregulation in the tropics. This paper details the first study of the climatic effects of altitude on lizard thermoregulatory behaviour in Sri Lanka and seeks to present new information on the importance of thermoregulation in tropical reptiles.

To explore thermoregulatory opportunities in reptiles the use of operative temperatures are far more valuable than air or substrate temperatures (Bakken, 1992). Operative temperatures are computed using physical models of the organism that approximate the heating and cooling rates of the real reptiles and have value in describing the distribution of possible body temperatures available. In this study, operative models were employed to determine the consequences for behaviour and body temperatures in the lizard *Calotes versicolor* in two habitats at different altitudes in the Knuckles Massif. The most widespread species of agamid lizard in Sri Lanka, *C. versicolor* operates largely as an arboreal sit-and-wait predator with a limited home territory. It is found over a range of differing biotopes from sea level up to 2000 metres. This makes *C. versicolor* an ideal subject for thermoregulation studies. In addition, we also present tentative mathematical models of general altitudinal influences on body temperatures in both *Calotes* species and other squamates from the region.

Methods and materials

Observations were made on two populations of *C. versicolor* in the Knuckles region (Bambaradeniya and Ekanayake, 2003). One population was observed at Hettipola, at 91 metres above sea level and a second in the area around Pitawala pathana, at more than 900 metres altitude. Plate 5 Figure 2 shows the study site at Hettipola, which was characterised by lowland scrub, including rivers and water tanks, agricultural land and areas of medium sized trees. During the study (July 2005), Hettipola experienced high temperatures with frequent hot winds, which are normal for the time of year (dry season). The lizards were in general observed in trees from which they frequently descended to capture prey. Plate 5 Figure 3 shows the study area at Pitawala Pathana, which was composed of dry patana grassland with scattered stands of shrubs and some small trees. The grassland was interspersed with areas of flat, dark-coloured rock which were occasionally used for basking. The territories of individuals appeared to be confined to the areas around single bushes. Frequent cloud cover and cool winds were a feature of the area.

Behaviour observations were continuous on 8 lizards for a mean time (with standard deviation) of 101±92.6 minutes for each individual at Pitawala pathana and on 5 lizards at Hettipola for 195.6±71.6 minutes both between 0900hrs and 1500hrs. Behaviour was categorised as: *Basking*, the lizard was positioned in open sunlight: *Partial Basking*, located in an area with dappled sunlight falling on the body or approximately half in sun and half in shade: *Shade*, in a fully shaded area with no sunlight falling on the body: *Locomotory Activity*, the lizard was involved in some form of movement. Here both the number of movements and the distances travelled were recorded. To minimise behavioural disturbance no attempt was made to approach or capture any of these animals. In order to gather representative information on body temperatures other lizards were captured by noose and measured immediately after capture by inserting a digital thermometer with a 130mm stainless steel sensor probe into the cloaca. Skin surface temperature was taken using a Electronique Frontal infra red detector (model TS112) directed at the flank. This instrument measures infrared energy being emitted from the lizard and has an error of less than 0.01C. There will, however, be some additional error due to the emissivity of *C.versicolor* skin. In

general, reptile skin has an emissivity of around 0.95 (Tracy, 1982).

In this paper we used cloacal temperatures for statistical comparisons since we found only little disagreement between skin surface temperature and cloacal temperature. The regression of the relationship, with skin surface temperature (T_{bs}) as the independent variable and cloacal temperature (T_b) as the dependent variable was,

$T_b = 1.03 \pm 0.08 T_{bs} - 1.21$, $r^2 = 91.2\%$ (1)

The r^2 is the adjusted value, where there will be no increase because of sample size alone. The equation is based on lizards from both study sites (see table 1) and shows both measurements were in good agreement, with the regression coefficient very close to the value of 1 required for parity. The high r^2 value and low standard error therefore indicate that analysis involving skin surface or cloacal temperatures would give similar results.

Operative temperatures at both sites were measured using copper cylinders with dimensions of 12cm in length and 2.5cm in diameter and 0.5 mm thick. These were painted green to reflect the general colour of the lizards – although *C. versicolor* has the ability for partial colour change. To represent the consequences of a lizard remaining in open sunlight continuously, one model was placed permanently in open sunlight. Two models were placed in dappled sunlight – one on the ground and one in a tree at a height of 1.5 metres. This was to represent the potential temperatures for a lizard for remaining continuously either in partial shade on the ground or in partial shade above the ground in a tree. Partial shade is the same way as defined for the lizards. A model was placed in total shade in order to represent the consequences for a lizard remaining in shade throughout the day. The model temperatures were measured approximately every 15 minutes, by directing the infrared detectors to the surface of the models in the same way skin surface temperature was measured in the lizards. The short 15-minute time intervals between measurements minimised the effects of operative temperature fluctuation, particularly at Pitawala pathana where wind speeds were variable (O`Conner, 2000).

Small thin walled copper models are good estimators of the temperatures available to small ectotherms since they respond rapidly to changes in temperature, with the small conduction distances limiting the internal thermal gradients that may obscure patterns of environmental temperature distribution (O`Connor *et al.*, 2000). The operative models are indicators of the potential heat available to the lizards in their environment and represent the point at which a lizard's body temperature would equilibrate if it made no movement or thermoregulatory adjustments – if it behaved as a thermoconformer. By recording the maximum and minimum temperatures we assumed that a lizard could either attain any body temperature within these extremes by spending all its time in either location or fluctuating body temperature between the highest and lowest available operative temperature by shuttling (Christian *et al.*, 1983). We also assumed that the lizard could equilibrate with dappled sunlight operative temperatures by either being half in sun and half in shade or spending 50% of its time within sun and shade. The type of operative model used is subject to debate (Shine and Kearney, 2001) but recent evidence suggests that operative model type is less important than previously thought (Vitt and Sartorius, 1999; Shine and Kearney, 2001).

Statistical analysis

To avoid problems of pseudo-replication, analysis was applied to the medians of percentages of behaviour of individual lizards i.e. giving n = 8 lizards at Pitawala pathana and n = 5 at Hettipola. This method avoids artificially inflating the degrees of freedom, inappropriately rejecting the null hypotheses and committing a type 1 statistical error (Lombardi & Hurlbert, 1996). Behaviour was analysed using non-parametric tests.

The body temperatures from lizards captured randomly were treated as single data points and were compared with their corresponding operative measurements. For statistical comparison between study sites, the data for operative temperatures were converted to the mean temperatures per hour and ANOVA applied. Comparisons of regression coefficients were made using *t*-tests based on the methods described by Bailey (1981).

Results

Behaviour

Figure 2 shows the behaviour patterns at different elevations with the data represented as the medians of the medians of individual lizards. Basking was greater at the higher elevation (Pitawala pathana *grand median* basking = 71%; Hettipola *grand median* = 0.94%) with the differences significant, Mann Whitney *U* – test $w = 76$, $p = 0.004$. Shade seeking was greater at Hettipola (*grand median* = 77.1%) than at Pitiwala (*grand median* = 24.5%) with the difference significant, $w = 42.0$, $p = 0.048$. Time spent in partial shade was greater at Hettipola (*median* percents 11.3 versus 16.7%) but the difference was not significant.

Activity was recorded both as the number of movements and distances travelled for each individual per hour. The number of locomotory movements was greater at Pitawala pathana (*grand median* with interquartile range = 21.4, 17.5 – 36.0, $n = 7$), than at Hittipola (*grand median* = 4.35, 1.8 – 14.9, $n = 5$). The difference was significant $w = 59.0$, $p = 0.03$. Although the distances travelled during locomotory movement was greater at Hettipola (*grand median* = 6.4, 0.7 – 18.2, $n = 5$) than Pitawala Pathana (*grand median* = 5.4, 2.6 – 8.1, $n = 7$) the difference was not significant, $w = 44.0$, $p = 0.87$.

Table 1. Operative temperatures and body temperatures of *C. versicolor*. Mean values are shown with standard deviations. Definitions are T_b = cloacal body temperature, n = sample sizes of body temperatures, To_{open} = operative temperatures in open areas, $To_{dappleG}$ = dappled areas on the ground, $To_{dappleT}$ = dappled areas on tree trunks and To_{shade} = shaded areas. Temperatures are in degrees centigrade. See text for statistical comparisons.

	T_b	n	To_{open}	$To_{dappleG}$	$To_{dappleT}$	To_{shade}
Pitawalla	25.6±2.4	19	27.7±2.4	26.0±2.6	24.9±1.4	23.9±1.3
Hettipola	36.1±1.9	22	38.6±3.8	33.4±1.7	33.1±1.4	31.9±1.7

Figure 2. Histograms of behaviour at different altitudes. The cells represent the medians of the medians of the percentages of behaviour of individual lizards. Figure 2A shows high altitude (Pitawala Pathana) and B low altitude (Hettipola). See text for further information.

Operative temperatures. Table 1 gives details of operative temperatures. Pooled operative temperatures for each site were significantly higher at Hettipola ($F_{(1,223)}=375.6, p<0.0001$). Microhabitat operative temperatures , open, dappled (either on tree trunks or on the ground) and shade, were also higher at Hettipola; ANOVA *F*- statistics from 44.12 – 251.04 all at $p < 0.0001$.

Body temperatures. Table 1 shows mean body temperatures with standard deviations. Mean body temperatures at Hettipola ($n = 22$) were significantly higher than at Pitawala pathana ($n = 19$); two sample *t*-test, $t = 15.28$, $p < 0.0001$, $d.f. = 39$. Body temperature variance was greater in the Pitawala pathana lizards ($v = 5.76$ versus $v = 3.61$). However, a Levene`s test for variance homogeneity showed that the difference was not significant ($L = 0.70$, $p = 0.41$). These results indicate both groups

of lizards had similar thermoregulatory precision.

Comparison of body and operative temperatures. At Pitawala pathana mean body temperatures were lower but not significantly lower than mean operative temperatures in open areas ($F_{(1,34)}$=3.02,p = 0.09), dappled operative temperatures on the ground ($F_{(1, 33)}$ = 0.18, p = 0.67) and dappled operative temperatures on tree trunks ($F_{(1,33)}$ = 1.31, p = 0.26). Body temperatures were significantly higher than shaded operative temperatures ($F_{(1,33)}$ = 6.16, p = 0.02). At Hettipola, mean body temperatures were significantly lower than open area operative temperatures ($F_{(1,60)}$ = 7.20, p = 0.009) but significantly higher than operative temperatures in dappled areas on the ground ($F_{(1,60)}$ = 36.6,) dappled operative temperatures on tree trunks ($F_{(1,60)}$ = 49.8) and shade operative temperatures ($F_{(1,60)}$ = 77.8) all at p<0.0001.

In general, body temperature and operative temperature variances were similar. Levene`s tests for homogeneity of variances set at the 95% interval, indicated significant differences only between Hettipola body temperatures and operative temperatures in open areas L = 3.6, p = 0.05 where body temperature variance was significantly lower.

General squamate body temperatures in relation to altitude

Body temperatures from a series of randomly captured reptiles from a range of altitudes within the Knuckles region have been related in a regression analysis. Two regressions have been calculated, one for a series of *Calotes spp* and a second from other lizards and snakes in which the data for *Calotes* have been included. Altitude (in metres) has been treated as the independent variable and body temperature as the dependent variable. A corrected coefficient of determination (r^2) has been applied to estimate the amount of variation in body temperature that can be explained by the variation in altitude. Tests for departures from a hypothetical equation with a 0 regression coefficient, which would indicate no relationship were applied. The results for *Calotes spp.* gave,

$$y = 36.26 - 0.010 \pm 0.001x,\ r^2 = 0.72 \quad (2)$$

with the departure from 0 significant (t = 8.96, p < 0.001, $d.f.$ = 32). For the series of squamate reptiles the relationship gave,

$$y = 37.23 - 0.013 \pm 0.0006x,\ r^2 = 0.79 \quad (3)$$

with the regression coefficient also significantly different from 0 (t = 19.4, p < 0.001, $d.f.$ = 101). Figure 3A shows the data for *Calotes spp* and Fig. 3B for the different squamate species. The lines taken through the data were calculated using equations (2) and (3). A t-test for differences between the regression coefficients at n - 4 degrees of freedom showed that the slopes were significantly different, t = 2.57, p <0.02, $d.f.$ = 154; equation (3) for the randomly captured squamates had a significantly steeper slope and hence a more pronounced relationship. Table 2 gives a list of the species used in the models with basic summary statistics.

The graphs clearly show that the highest body temperatures were from reptiles found in lowland areas and the lowest from those in the mountains. We recognise that there are inherent difficulties in this approach; for example not all species may be baskers, different species may operate at different body temperatures and some animals may not have been basking at the time of capture and so on. Indeed, the difference between equations (2) and (3) may be partly due to less thermoregulatory effort in

several of the non-*Calotes* species; *Calotes sp.* are primary basking reptiles whilst some of the others may not be. However, the general pattern of fit, the high r^2 and low standard errors, indicate a relationship between body temperatures and altitude and warrants further investigation.

Figure 3. General plots of body temperature and altitude in squamate reptiles from the Knuckles region. Figure 3A shows the data for *Calotes* species and 3B for other lizards (including *Calotes*) and snakes with the lines representing equations (2) and (3). See text for further details

Discussion.

The results show that *C. versicolor* compensates for reduced thermal resources at higher altitude by increasing basking intensity and number of locomotory movements. However, despite the increased basking effort, the lizards were still unable to maintain similar body temperature to the lizards at Hettipola which appear to be a consequence of the thermal constraints of the mountain climate. What effect does this have on the lizards general behaviour and ecology? This depends on the evolutionary processes operating on thermal biology. The static theory of thermal evolution predicts that thermal benefits will be fixed and body temperatures must be maintained if the physiological benefits from temperature are to be retained (e.g. Hertz *et al.*, 1983;Crowley, 1985; Van Damme *et al.*, 1990). An alternative labile theory argues that thermal optima are dynamic and will evolve with changing environments (Huey and Bennett, 1987). If the static theory is in operation, the lowered body temperatures in the Pitiwala lizards must indicate reduced physiological performance, for instance sprint speed (e.g. Torr and Shine, 1993), the ability to chase and secure prey items, prey handling time (Avery and Mynott, 1990) and the ability to escape predators (Avery, *et al.*, 1982). It has been suggested that locomotory capacity may not be critical for lizards that rarely venture far from cover (Huey and Bennett, 1987), as was the case for *C. versicolor* which usually stayed close to bushes (see Fig 1). Escape behaviour might occur earlier at lower body temperatures and when vegetation density is sparse (Martin and Lopez, 1995). Additionally, ectothermic prey might reasonably be expected to experience the same Q_{10} effects (Huey, 1982) and hence securing prey or escaping from ectothermic predators may be a limited problem if at all. Ectothermic predators were not recorded at Pitawala pathana although several were observed at Hettipola, including two species of varanids (*Varanus bengalensis* and *V. salvator*) and several colubrid snake species. Of these the widely foraging *V. bengalensis* may be the most important as they were observed searching both terrestrial and arboreal habitats.

Greater basking intensity and locomotory adjustment with altitude has been observed in other reptiles, for example *Lacerta bedriagae* (Bauwens, *et al.*, 1990). High altitude *Lacerta monticola* employ basking orientation to enhance heating rates (Lopez *et al.*, 1995). Other forms may respond to increased altitude by physiological adjustment, as found in the New Zealand skink *Leiolopisma maccanni* which apparently did not change behaviour or exploit microhabitats with higher operative temperatures (Spencer and Grimmond, 1994). When thermal resources became limited, female *Testudo hermanni* did not increase basking and operated at lower body temperatures (Meek, 1988). Similarly, body temperature differences with altitude, as found in *C. versicolor*, have also been recorded in other lizards (e.g. Amat et al 2003, Gvozdik, 2002). For example, in *Zootoca* (= *Lacerta*) *vivipara* populations living at altitudes of 2000-2200m, body temperatures were 3-5°C lower than those from 25m above sea level (Van Damme et al, 1990). The montane *Z. vivipara* were found with body temperatures that seriously affected locomotory movement but laboratory studies showed no parallel shift in optimal temperatures for running – i.e. thermal set points were resistant to directional selection. Van Damme *et al.*, (1989) found greater variation in body temperatures with altitude, which differs from the results in this study where there was an agreement in precision of

thermoregulation between populations. This indicates careful thermoregulation even outside the set point range, which may be due to tree trunks in open habitats representing very low cost microhabitats that favour precise thermoregulation; the distances between sunlit and shaded areas are small (Huey, 1982) and hence the costs of thermoregulatory precision are low.

The general cost of cool climates on thermoregulation may depend on the lifestyle of the species in question. Compared to *Calotes versicolor*- a sit-and–wait predator living in relatively open habitats, the costs for thermoregulation for a foraging predator living in cooler rather complex habitats may be relatively high (Avery, 1976). Indeed a foraging lifestyle, in addition to greater body mass and hence slower heating rates, may contribute to the absence of *V. bengalensis* at Pitawala pathana. The ability to exploit habitats with low temperatures is a potential fitness advantage and apparently enables *C. versicolor* to exploit areas with cool seasons or high elevations. The costs are increased thermoregulatory effort with a premium on high basking intensity and adjustment to a lower set point temperature. In contrast, the premium on shade seeking and regulation of body temperature below maximum operative temperatures in the Hettipola lizards suggests they were close to physiological optimums. Nevertheless, the time a lizard is able to operate at optimum temperatures may be an important consideration since shorter periods at physiological optimum temperatures may result in less assimilated energy per annum which would have ecological consequences (Angilletta, 2001). A species of skink (*Lygosoma punctata*) and two anurans, *Euphlyctis cyanophlictis* and *Limnonectes limnocharis*, were observed in good numbers at Pitawala pathana and it would be interesting to know if there are differences in strategies to exploit the available thermal resources. Additionally, although we have shown good evidence for thermoregulation and the constraints of altitude and low temperature on thermoregulatory behaviour, it is not possible with any certainty to address the central question of the ecological costs on preferred body temperatures for physiological processes in *C. versicolor*. This requires laboratory heat gradient studies to examine whether the temperature effects on physiology in *C. versicolor* are static or labile. Future research could focus on these questions.

Acknowledgements

We wish to thank: Mr. Sarath Fernando, Director General, Forest Department for permission (FRC/5 and FRC/6) and Director General, Department of Wildlife Conservation for approvals (WL/3/2/1/14/12) granted to Anslem de Silva, Aaron Bauer and C. Austin to conduct the above study. University of Edinburgh, United Kingdom for funding and supporting Project Knuckles 2005.

We thank Dr Roger Avery for critically reviewing the manuscript.

Literature cited

Amat, F., G.A. Llorente, and M. A. Carretero. 2003. A preliminary study on thermal ecology, activity times and microhabitat use of *Lacerta agilis* in the Pyrenees. *Folia Zool.* 52, 413 – 422.

Angilletta, M.J. 2001. Thermal and physiological constraints on energy assimilation in a widespread lizard (*Sceloporus undulatus*). *Ecology* 82, 3044 – 3056.

Avery, R.A. 1976. Thermoregulation, metabolism and social behaviour in Lacertidae. *In* Bellairs, Ad`A and Cox, C.B. (Eds), *Morphology and Biology of Reptiles* 245 – 259. Linnean Society Symposium Series 3. Academic Press, London.

Avery, R.A., J.D. Bedford, and C.P. Newcombe. 1982. The role of thermoregulation in lizard biology: predatory efficiency in a temperate diurnal basker. *Behav. Ecol. Sociobiol.* 11, 261 – 267.

Avery, R.A. and A. Mynott 1990. The effects of temperature on prey handling time in the common lizard *Lacerta vivipara*. *Amphibia – Reptilia* 11, 111 – 122.

Bakken, G. S. 1992. Measurement and application of operative temperatures in ecology. *Amer. Zool.* 32, 194 – 216.

Bailey, N.T.J. 1981. *Statistical Methods in Biology*. London, English Universities Press.

Bambaradeniya C. N. B. and S. P. Ekanayake. 2003. *A Guide to the Biodiversity of Knuckles Region*, IUCN, Colombo.

Bauwens, D. A.M. Castilla, R Vanne Damme, and R.F. Verheyen. 1990. Field body temperature and thermoregulatory behaviour of the high altitude lizard *Lacerta bedriagae*. *J. Herp*. 24, 88 – 91.

Blouin- Demers, G and P.J. Weatherhead. 2001. Thermal ecology of black rat snakes (*Elaphe obsoleta*) in a thermally challenging environment. *Ecology* 82, 3025 – 3043.

Brown, G.P. and P.J. Weatherhead. 2000. Thermal ecology and sexual size dimorphism in northern water snakes *Nerodia sipedon*. *Ecol. Monogr*. 70. 311 – 330.

Christian, K.A., C.R. Tracy & W.P Porter. 1983. Seasonal shifts in body temperature and use of microhabitats by the Galapagos land iguana. *Ecology* 64, 463 – 468.

Crowley,S.R. 1985. Thermal sensitivity to sprint - running in the lizard *Sceloporus undulatus*: support for the conservative view of thermal physiology. *Oecologia* 66, 219 – 225.

Gvozdik, L. 2002. To heat or save time? Thermoregulation in the lizard *Zootoca vivipara* in different thermal environments along an altitudinal gradient. *Can. J. Zool*. 80, 479 – 492.

Hertz, P.E., R.B. Huey, and E Nevo. 1983. Homage to Santa Anita: thermal sensitivity of sprint speed in agamid lizards. *Evolution* 37, 1075 – 1084.

Huey, R.B. 1982. Temperature, physiology and the ecology of reptiles. In: *Biology of the Reptilia* 12, *Physiology* C; *Physiological Ecology* 25 – 91. Gans, C & Pough, F.H. (Eds). Academic Press, London.

Huey, R.B. and M. Slatkin. 1976. Costs and benefits of lizard thermoregulation. *Q. Rev. Biol*. 51, 363 – 384.

Huey, R.B. and A. F. Bennett. 1987. Phylogenetic studies of coadaptation: preferred temperatures versus optimal performance temperatures of lizards. *Evolution* 41, 1098 – 1115.

Lombardi C.M, & S. H. Hurlbert. 1996. Sunfish cognition and pseudoreplication. *Anim. Behav*. 52, 419 – 422.

Lopez, M.J., L. M. Carrascal, and A. Salvador. 1995. Adjustment of basking postures in the high altitude Iberian rock lizard. *Can J. Zool* 73, 1065 – 1068.

Luiselli,L. and C. G. Akani. 2002. Is thermoregulation really unimportant for tropical reptiles? Comparative study of four sympatric snake species from Africa. *Acta Oecol* 23, 59 – 68.

Magnusson,J.J., L.B. Crowder, and P.A. Medvick. 1979. Temperature as an ecological resource. *Am.Zool*. 19, 331 – 334.

Martin, J and P. Lopez. 1995. Influence of habitat structure on the escape tactics of the lizard *Psammodromus algirus*. *Can. J. Zool*. 73, 129 – 132.

Meek, R. 1988. The thermal ecology of Hermann`s tortoise (*Testudo hermanni*) in summer and autumn in Yugoslavia. *J. Zool. Lond*. 215, 99 – 111.

O`Connor, M.P. 2000. Extracting operative temperatures from temperatures of physical models with thermal inertia. *J. Therm Biol*. 25, 329 – 343.

O`Conner,M.P., L.C. Zimmerman, E.M. Dzialowski, and J.R. Spotila. 2000. Thick-walled physical models improve estimates of operative temperatures for moderate to large-sized reptiles. *J.Therm. Biol*. 25, 293 – 304.

Pearson, O.P. 1954. Habits of the lizard *Liolaemus multiformis* at high altitudes in southern Peru. *Copeia* 1954, 111 – 116.

Shine, R. and M. Kearny. 2001. Field studies of reptile thermoregulation: how well do physical models predict operative temperatures. *Funct. Ecol*. 15, 282 –288.

Shine,R. and T. Madsen. 1996. Is thermoregulation unimportant for most reptiles? An example using water pythons (*Lyasis fuscus*) in tropical Australia. *Physiol. Zool* 69, 252-269.

Spencer, N.J. and N.M. Grimmond. 1994. Influence of elevation on the thermoregulation

of two sympatric lizards. *New Zeal. J Zool.* 21, 379 – 385.

Strelnikov, S.D. 1944. Importance of solar radiation on the ecology of high mountain reptiles. *Zool. Zh.* 23,250 –357.

Torr, G.A. and R. Shine. 1993. Experimental analysis of thermally dependent behaviour patterns in the scincid lizard *Lampropholis guichenoti*. *Copiea* 1993, 850 – 854.

Tracy, C.R. 1982. Biophysical modelling in reptilian physiology and ecology. In, *Biology of the Reptilia* C: *Physiological Ecology*, 275 – 321. Gans, C and Pough, F.H. (Eds.) Academic Press, London.

Van Damme, R, D. Bauwens, A.M. Castilla, and R.F. Verheyen. 1989. Altitudinal variation of the thermal biology and running performance in the lizard *Podarcis tiliguerta*. *Oecologia* (Berlin) 80, 516 – 524.

Van Damme, R., D. Bauwens, and R.F Verheyen. 1990. Evolutionary rigidity of thermal physiology: the case of the cool temperate lizard *Lacerta vivipara*. *Oikos* 57, 61 – 67.

Vitt, L.J. and S.S. Sartorius. 1999. Tidbits and lizard models: the utility of electronic devices in field studies of ectotherm thermoregulation. *Funct. Ecol.* 13, 670 – 674.

Table 2. List of squamate species used to compute equations (2) and (3) with summary statistics for the data subsets. Where appropriate, means of altitudes and body temperatures (Tb) are given with standard deviations and sample sizes n. Standard deviations of 0 for altitude indicates that the animals were located at the same elevation. Data for *C. versicolor* are given in table 1.

Species	Mean Altitude	Mean Tb	N
Calotes calotes	696.8±77.8	26.7±3.1	6
Calotes liocephalus	1370.6±131.1	22.9±1.1	3
Calotes liolepis	1238.0 -	30.0 -	1
Cophotis ceylonensis	996.0 -	26.7 -	1
Lyriocephalus scutatus	694.3±54.6	27.5 ±0.5	3
Ceratophora tennentii	1176.0±134.1	21.3±2.6	43
Otocryptis wiegmanni	942.5±324.5	25.1±3.6	2
Otocryptis sp	743.0±16.0	28.1±0.1	2
Lankascincus sp	1014.0 -	23.8 -	1
Lankascincus fallax	1065.0 -	22.5 -	1
Mabuya sp	962.0 -	38.5 -	1
Chalcidoseps thwaitesii	924.0±0.0	25.3±0.4	4
Cnemaspis sp	743.0 -	30.9 -	1
Cyrtodactylus fraenatus	1000.5±264.1	25.2 ±2.2	4
Geckoella triedra	1037.3±80.1	23.4±0.7	3
Hemidactylus depressus	668.0±50.0	27.3±1.9	2
Nessia sp	1025.0 -	20.7 -	1
Haplocercus ceylonensis	1110.0 -	27.4	1
Uropeltis sp	1095.0±0.0	21.6±0.75	2
Amphiesma stolatum	996.0 -	24.7 -	1
Ptyus mucosus maximus	591.0 -	31.2 -	1
Oligodon sublineatus	1024.0 -	24.3 -	1
Ahaetulla nasutus	743.0 -	25.6 -	1
Trimeresurus trigonocephalus	618.0 -	28.0 -	1

Figure 2. Histograms of behaviour at different altitudes. The cells represent the medians of the medians of the percentages of behaviour of individual lizards. Figure 2A shows high altitude (Pitawala) and B low altitude (Hettipola). See text for further information.

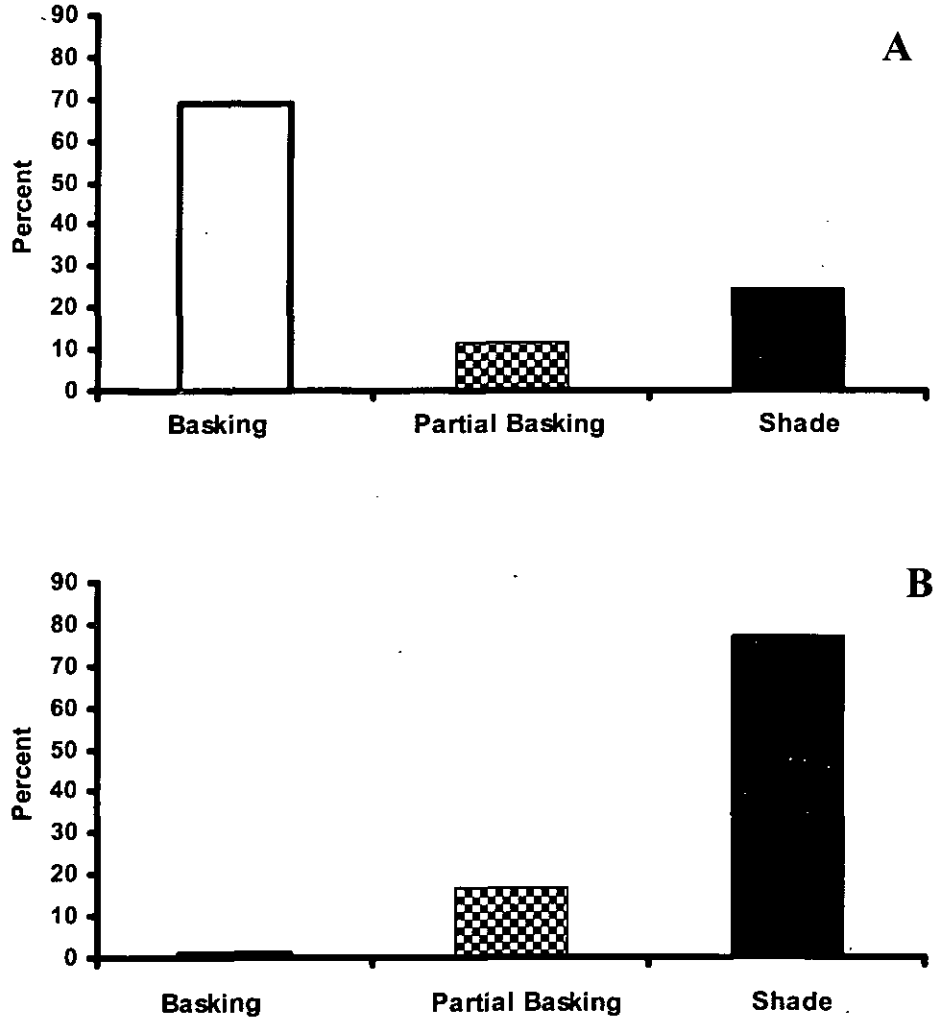
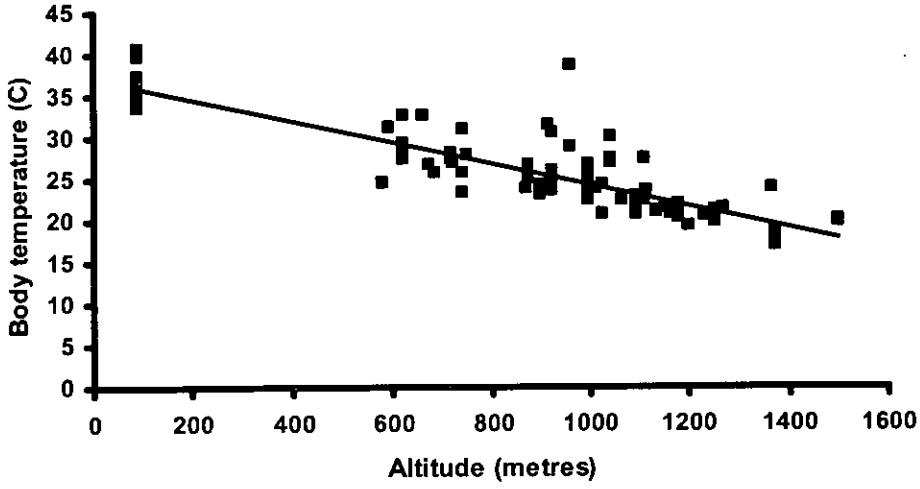
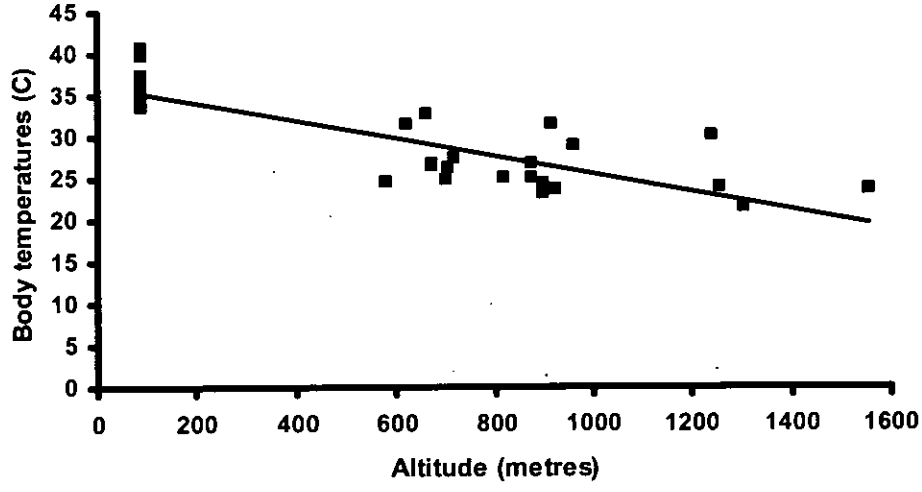


Figure 3. General plots of body temperature and altitude in squamate reptiles from the Knuckles region. Figure 3A shows the data for *Calotes* species and 3B for other lizards (including *Calotes*) and snakes with the lines representing equations (2) and (3). See text for further details





The Diversity of the Dumbara Mountains (The Knuckles Massif, Sri Lanka): With special reference to its herpetofauna.
Lyriocephalus Special issue, 2005 November, Volume 6 Numbers 1 & 2: 95-100
ISSN 1391-0833

OBSERVATIONS ON THE SKINKS INHABITING THE KNUCKLES MASSIF: WITH SPECIAL REFERENCE TO GENUS *LANKASCINCUS*

Anslem de Silva[1], C. C. Austin[2], A. M. Bauer[3], S. Goonewardene[4], J. Drake[4], P. de Silva[1], T. Shripathy[5], S. Ramesh[5], K. Suthagar[5] & A. Kajatheepan[6]

[1]*15/1 Dolosbage road, Gampola, Sri Lanka. Email: kalds@sltnet.lk*
[2]*Museum of Natural Science, Louisiana State University, 119 Foster Hall, Baton Rouge, LA 70803 USA. Email: ccaustin@lsu.edu*
[3]*Department of Biology, Villanova University, 800 Lancaster Avenue, Villanova, Pennsylvania 19085, USA. Email: aaron.bauer@villanova.edu*
[4]*97, Battersea Park Road, London, SW9 4DU, UK. E-mail: hsr.wild@gmail.com (University of Edinburgh, UK)*
[4]*Creagard, Isle of Mull, PA75 6RA, UK. E-mail: jfdrake@gmail.com (University of Edinburgh, UK)*
[5] *University of Eastern Sri Lanka (Chenkaldi),* [6] *University of Jaffna, Sri Lanka*

Keywords: *Dasia halianus, Lankascincus. Lygosoma, Mabuya*, Knuckles

Introduction

The island of Sri Lanka has been identified as biodiversity hotspot (Bossuyt *et al.*, 2004). Despite its close proximity to mainland India, Sri Lanka has a species rich and highly endemic herpetofaunal assemblage. In particular the scincid lizards of Sri Lanka are highly diverse and abundant. The literature records 30 species (Das & de Silva, 2005, de Silva 2001). During the Knuckles expedition we were able to locate and identity 14 species of skinks inhabiting various ecological niches in the Knuckles ecosystem. Thus, the skinks constitute a prominent group of vertebrates that adds to the reptile diversity of the Knuckles ecosystem. Of the skinks, Greer (1991) described the endemic genus *Lankascincus*. All congeners so far known (*deignanai, deraniyagalae, gansi, fallax, taprobanensis,* and *taylori*) are endemic to Sri Lanka. *Lankascincus* are the most common skinks found on the island. Nonetheless, many aspects of its biology and systematics are poorly understood.

Preliminary ecological accounts for three scincid lizards: *Chalcidoseps thwaitesii, Nessia bipes* and *N. sarasinorum* inhabiting the Knuckles are discussed in the present volume (de Silva *et al.*, 2005i, de Silva *et al.*, 2005j).

Methods

Field methods employed to locate skinks were: visual encounter studies, patch sampling, leaf litter quadrate sampling, and canopy investigations. Most skinks when observed were collected by hand and the following data were recorded in a structured questionnaire: date, time, GPS location, locality, habitat, microhabitat, species, gender, measurements, and defects. A fæcal sample was collected from specimens from each new location in to a bottle containing 10% formaldehyde. The stool samples were taken to the research laboratory of Department of Veterinary Pathobiology, Faculty of Veterinary Medicine & Animal Science, University of Peradeniya, for investigations related to intestinal parasites. All animals were released back after photographing in the spots where they were collected

Results

Species of Scincidae observed inhabiting the Knuckles Massif

Genus: *Chalcidoseps* Boulenger 1887.

1. *Chalcidoseps thwaitesii* (Günther, 1872). English: Fourtoe snakeskink, Sinhala: Caturanguli sarpiyahikanala. Status: Endemic.

Notes: common and widely distributed for details refer de Silva *et al.*, (2005) in the present volume.

Genus: *Dasia* Gray, 1839.
2. *Dasia halianus* (Haly & Nevill, 1887). English: Haly's tree skink, Sinhala: Helige rukhiraluva. Status: Not endemic.

Notes: On 28 July 2005 an adult early gravid female (SV – 86 mm and Tail – 57 mm, Axila Groin-45mm, 17 grams) was observed around 11 am at the base of a large tree at Pitawala Pathan (approximately 820 m above sea level). It was injured, probably attacked by a bird (Plate 6. Figure 1). Another specimen was observed on the same day crossing the road around 12 noon at Illukkumbura it quickly disappeared and burrowed into the loose soil (Plate 6. Figure. 2). Immediate search by five persons could not locate it. Samarakoon (2004) reported another female *Dasia halianus* (total length 130 mm) falling from a *Terminalia arjuna* tree around 14.30 hours at Pallegama. Our observations indicate that *Dasia halianus* exhibit arboreal, terrestrial as well as fossorial habits confirming Dearniyagala's (1953) observations made under captivity.

Genus: *Lankascincus* Greer, 1991.
Notes: Of the six known *Lankascincus* species (Greer 1991), five were encountered in the Knuckles. Some distinct distribution patterns were observed. *Lankascincus fallax* was the common species encountered in the lowland drier parts as well as degraded habitats in Knuckles. Where as *Lankascincus taprobanensis* was encountered in a wider range in the Knuckles montane and sub-montane forests, including monoculture plantations (e.g. Pines, Acacia and cardamom) and in anthropological habitats. *Lankascincus taylori* was common with large populations in monoculture plantations (e.g. Pines) hiding under stones, logs and leaf litter. Where as *Lankascincus deraniyagalae* and *Lankascincus gansi* were uncommon and were restricted montane forests. *Lankascincus* was observed often sympatric with *Chalcidoseps thwaitesii, Nessia bipes* and *Mabuya* species. Most gravid females that were observed, contained two eggs. The following *Lankascincus* species were observed:
3. *Lankascincus deraniyagalae* Greer, 1991. English: Deraniyagal's lankaskink, Sinhala: Daraniyagalge lakhiraluva. Status: Endemic.
Notes: Five specimens (Plate 6. Figure 3) were observed in Illukumbura (638m) found in Tropical Mixed Evergreen Forest under logs and leaf litter. The range of total length (n = 6) = 66 – 113mm and range of weights were 1.75-2.00 g..

4. *Lankascincus fallax* (Peters, 1860). English: Common lankaskink, Sinhala: Sulaba lakhiraluva. Status: Endemic.
Notes: 118 specimens were observed in Pine Plantation, Riverine forest, Scrub Forest, Tropical Mixed Evergreen Forest and Upper Montane Forest in straw, inside termite mounds, leaf litter, on rock, root systems, under logs, under rocks and in home gardens. Observed around Dawattagalla (1344m), Dehigolla (1122m), Elkaduwa (999m), Gammaduwa (1002m), Illukumbura (476m), Kalupahana (924m), Kandegama (750m), Karakolamana (162m), Kobonilagala (1379m), Laggala - Pallegam (571m), Lakegala (434m), Liyangolla (634m), Navanagala (1200m), Nitre cave (1065m), Pitawala (579m), Puwakpitiya (550m), Rambukotuwa (242m), Riverston (1212m), Sphinx rock (951m), Sulugune (170m) and Yahangala (300m). The range of total length (n = 6) = 66 – 113mm and range of weights were 1.75-2.00 g. Gravid female and hatchlings (n=3) were observed during the study period.

5. *Lankascincus gansi* Greer, 1991. English: Gans's lankaskink, Sinhala: Gansge lakhiraluva. Status: Endemic.
Notes: Three specimens (Plate 6. Figure 4) observed in Human agriculture and Lower Montane Rock Outcrop Forest under rocks. Bambugala (824m) and Lakegala (553m). The range of total length (n = 2) = 56 – 91 mm and range of weights were 1.25-1.50 g. Gravid female was observed in September.

6. *Lankascincus taprobanensis* (Kelaart, 1854). English: Smooth lanka skink, Sinhala: Sumudu lakhiraluva. Status: Endemic.
Notes: 18 specimens (Plate 6. Figure 5) were observed in Riverine Forest, Lower Montane Forest, Tropical Mixed Evergreen Forest and Upper Montane Forest at Kobonilagala (1379m), Medamahanuwara (1033m), Dawattagalla (1344m), Riverston (1212m), Sphinx Rock (576m), Kandegama (750m), in

the following Microhabitats dead vegetation, leaf litter, ground, under logs and under rocks. The range of total length (n = 2) = 43 – 95mm and range of weights were 0.50-2.00 g. Gravid female and hatchlings (n=4) were observed during the study period.

7. *Lankascincus taylori* Greer, 1991. English: Taylor's lanka skink, Sinhala: Telorge lakhiraluva. Status: Endemic.
Notes: 27 specimens were observed and were found in Tropical Mixed Evergreen Forest, Lower Montane Forest, Riverine Forest and Pine plantations. It was observed around Corbet's Gap (688m), Dumbanagala (1049m), Illukkumbura (429m), Kandegama (750m), Lakegala (434m), Pitawala (836m), Rambukotuwa (242m) and Yahangala (770m), under rocks, leaf litter, humus and under logs. The range of total length (n = 9) = 72 – 133mm and range of weights were 0.50-2.50 g. Gravid females (n=3) and hatchling were observed in September.

Genus: *Lygosoma*
8. *Lygosoma punctatus* (Gmelin, 1799). English: Dotted skink, Sinhala: Tit hiraluhikanala. Status: Not endemic.
Notes: 12 specimens of *Lygosoma punctatus* was observed from around 300 to 1300 m above sea level in the Knuckles. They were more confined to degraded open habitats and close to anthropogenic habitats. Though they were more a subfossorial nature, we observed on several occasions juveniles basking on heated up rocks during the day. Observed around Deanston (1250m), Kalupahana (862m), Kobonilla (1100m), Lakegala (553m) and Pitawala (836m), under rocks and under logs. The range of total length (n = 5) = 72 – 167mm and range of weights were 8.00-9.00 g.

9. *Lygosoma singha* (Taylor, 1950). English: Taylor's skink, Sinhala: Taylorge hiraluhikanala. Status: Endemic.
Taylor (1950) described *Lygosoma singha* from one specimen without distribution location. Taylor recorded the identification key for *Lygosoma singha* and *Lygosoma punctatus* as:
Lygosoma punctatus = 24-26 scale rows.
Lygosoma singha = 28 scale rows, 4 thin dark lines on the anterior dorsal aspect.
During the Project Knuckles 2005 we observed a specimen (total length of 157mm and a weight of 8.00 g) which fitted to most characters given by Taylor for *Lygosoma singha* (Plate 6. Figure 6). However, some characters (e.g. scales between adpressed limbs) were different. Alpha taxonomy and molecular investigations of this specimen will be conducted. If it proves that what we observed at Knuckles is *Lygosoma singha*, it will be the first authentic record after 55 years (Plate 6. Figure 6).

Genus: *Mabuya* Fitzinger, 1826.
10. *Mabuya beddomii* (Jerdon, 1870). English: Beddome's stripe skink, Sinhala: Vairan hikanala. Status: Not endemic.
Notes: *Mabuya beddomii* (Plate 6. Figure 7) was observed in Puwakpitiya (519 m above sea level) in a thick forest with large tall trees, streams and ground with a thick layer of leaf litter. We also observed it at Elkaduwa (999 m above sea level). It was not commonly seen as *Mabuya macularia*. Like most *Mabuya* species, *M. beddomii* was quick to escape. The range of total length (n = 2) = 171- 183mm and range of weights were 11.00- 12.50 g. One was Gravid female with 2 eggs were observed in September.

11. *Mabuya carinata lankae* Deraniyagala, 1953. English: Common skink, Sinhala: Sulaba hikanala. Status: unique at sub-species level.
Notes: *Mabuya carinata lankae* is the largest scincid lizard in the country. It is a common and widely distributed species which is mainly confined to degraded forest patches, anthropogenic habitats and along roads. Basking in hot sun is common. 18 specimens were observed in Human agriculture and Riverine Forest habitats. The range of total length (n = 2) = 188 – 310mm and range of weights were 13.0-14.00 g. One Gravid female and hatchling were observed during the study period .

12. *Mabuya macularia maculara* (Blyth, 1853). English: Bronzegreen little skink, Sinhala: Pingu hikanala. Status: Not endemic.
Notes: *Mabuya macularia* (Plate 6 Figure 8) was the commonest *Mabuya* species observed in degraded habitats, mainly rock

outcrops near forests. Basking on heated up rock surfaces during the day and active foraging on rock surfaces is common. Presently alpha taxonomy and molecular investigations of this species are been investigated. Nine specimens were observed in Lower Montane Forest, Riverine Forest, Tropical Mixed Evergreen Forest and Upper Montane Forest habitats. The range of total length (n = 3) = 99 – 175mm and range of weights were 9.50-13.00 g. Gravid females (n=2), a hatchling was observed in during the study period.

Genus: *Nessia* Gray, 1839.
13. *Nessia bipes* Smith, 1935. English: Smith's snakeskink, Sinhala: Smithge sarpahiraluva. Status: Endemic.
Notes: This dominant skink that is widely distributed in many parts of the Knuckles and account on this skink is included in this publication (de Silva *et al.*, 2005j) (Plate 7. Figure 5).

14. *Nessia sarasinorum* (Müller, 1889). English: Sarasin's snakeskink, Sinhala: Sarasinge sarpahiraluva. Status: Endemic.
Nessia sarasinorum (Plate 7. Figure 6) was observed in one locality on the north east Knuckles.

Discussion
Lankascincus is a lygosomine scincid within the larger lygosomine radiation representing an independent lineage separate from the *Eugongylus*-, *Mabuya*-, *Egernia*-, or *Sphenomorphus*-groups (Austin *et al.*, 2004).

Lankascincus is arguably the most abundant scincid lizard we observed at the Knuckles range of mountains. It was the most common reptile species observed in the leaf-litter forest floor quadrats investigated. Of the 39 plots assessed in different vegetation habitats, *Lankascincus* was observed in 21 plots (Table 1). Also *Lankascincus fallax* had been observed by all previous workers at Kncukels (Table 2).

Members of the genus range throughout the entire island from such diverse habitats as humid rainforest, arid scrub forest, vicinity of human settlements, and moist montane forests (up to 2100m).

During the Knuckles survey we collected one species of *Lankascincus* species which could not be identified using available keys. Presently molecular as well as alpha taxonomical work is in progress.

The major result from this study is that the endemic *Lankasincus* represents a distinct lineage of the lygosomine scincid radiation (Austin *et al.*, 2004). This result compliments ongoing work in the vertebrate assemblages of Sri Lanka that reinforce the diversity and uniqueness of the Sri Lankan fauna (Bossuyt *et al.*, 2004). Additionally, it illustrates the grave need for additional taxonomic and phylogenetic work on Sri Lankan lizards.

Acknowledgements
We wish to thank: Mr. Sarath Fernando, Director General, Forest Department for permission granted to (AdS, AB and CA) (FRC/5 and FRC/6) to conduct the above study. Director General, Department of Wildlife Conservation, Mr. H. D. Rathnayake for approvals (WL/3/2/1/14/12). The Forest Department officers at Loolwatte and Illukumbura for their friendly support throughout the study. Manel Goonasekera, Head Department of Biological Sciences, Rajarata University of Sri Lanka for her support from the inception of the project. University of Edinburgh, UK for the approval given (to University of Edinburgh students) and the generous grant. Royal Geographical Society of UK for the grant. A special thanks to Laura Packham, Polly Bramham, Alasdair Ford, Douglas Fraser and A. J. G. Burns for their help in the field to collect data.

This research was funded in part by National Science Foundation grants DEB 0445213 and DBI 0400797 and by a Louisiana State University Faculty Research grant for CA. Aaron Bauer was supported by Villanova University and by Grant DEB 0515909 from the National Science Foundation.

Literature cited

Austin, C. C., I. Das & Anslem de Silva. 2004. Higher-level molecular phylogenetic relationships of the endemic genus *Lankascincus* from Sri Lanka based on nuclear DNA sequences. *The herpetology of Sri Lanka: current research (including the Proceedings of the Fourth World Congress of Herpetology, Sri Lankan papers and the Nilgala Expedition papers). Lyriocephalus* Special Issue. Vol. 5 , Nos. 1 & 2: 11-22.

Bambaradeniya, C. N. B., & S. P. Ekanayake. 2003 *A Guide to the Biodiversity of the Knuckles Forest Region.* IUCN, Sri Lanka Country Office, Colombo. 68 pp.

Bossuyt, F., M. Meegaskumbura, N. Beenaerts, D. J. Gower, R. Pethiyagoda, K. Roelants, A. Mannaert, M. Wilkinson, M. M. Bahir, K. AManamendra-Arachchi, P. K. L. Ng, C. J. Schneider, O. O.V., and M. C. Milinkovitch. 2004. Local endemism within the Western Ghats-Sri Lanka Biodiversity hotspot. Nature 306:479-481.

Das, I. & Anslem de Silva. 2005. *A photographic guide to snakes and other reptiles of Sri Lanka.* New Holland, UK, 144 pp.

De Silva, Anslem S. Molur & S. Walker. 2000. *Conservation Assessment and Management Plan CAMP Report for amphibians and selected taxa of reptiles of Sri Lanka.* Conservation Breeding Specialist Group, Sri Lanka. 226 pp.

de Silva, Anslem., A. M. Bauer, C. Austin, S. Goonewardene, J. Drake & P. de Silva. 2005i. *Chalcidoseps thwaitesii* (Günther, 1872) (Reptilia: Scincidae) four-toed skink: preliminary observation. *Lyriocephalus* Special issue, Volume 6 Numbers 1 & 2:

de Silva, Anslem., A. Bauer, C. Austin, S. Goonewardene, J. Drake, A. Balasubramaniam, C. Rajendran, V. Pathmadevan, M. Fernando & K.Sureskumar. 2005j. Notes on *Nessia* species inhabiting the Knuckles massif with special reference to *Nessia bipes* Smith, 1935 (Reptilia: Scincidae): the dominant snake skink. *Lyriocephalus* Special issue, Volume 6 Numbers 1 & 2:

Ginige, P. 1995. Reptile fauna of the Knuckles Range, Sri Lanka, *Lyriocephalus.* 1(1 & 2): 38–43.

Greer, A. E. 1991. Lankascincus a New Genus of Scincid Lizards from Sri Lanka, with Descriptions of Three New Species. *Journal of Herpetology,* 25(1): 59-64.

IUCN Sri Lanka & Forest Department. 1994. *Management plan for the conservation of the Knuckles Forest. Phase 2.* Forest Department, Colombo. 58 pp + appendices.

Rathnayake, N. D, A. N. Weerasinghe, K. Amarasinghe, C. Gamlath, D. Rathnayake, C. Irrugalrathne & H. Wijesinghe. 1999. *An ecological study on flora and fauna of Knuckles range – Sri Lanka (Northern region).* Youth Exploration Society of Sri Lanka, Peradeniya, 33 pages (mimeographed).

Samarakoon, S. M. M. 2004. *Dasia halianus* (Reptilia: Scincidae) a new locality record. *The herpetology of Sri Lanka: current research (Including the Proceedings of the Fourth World Congress of Herpetology, Sri Lankan papers and the Nilgala Expedition papers). Lyriocephalus* Special Issue. 2004, Vol. 5 , Nos. 1 & 2:

Table 1
***Lankascincus* species observed in the forest leaf litter plots (Knuckles Project 2004)**

Plot No	Date	Location	Habitat	Altitude (in meters)	*Lankascincus* speceis
1	15 July	Pine plantation near Corbett's gap	Pine, rocky, Burnt 2 days ago	1300	7m, 6f
2	15 July	Do – below road	Close to above	1300	5m, 6f
3	16 July	Pine plantation near forest office	Pine	1227	1m, 6f, 2NS, 6 eggs
4	16 July	Pine plantation 1 km from forest office	Pine and weeds	1134	16NS
5	16 July	Near Kobonila	Pine	984	1m, 1f
7	22 July	Near meemure	Pine		7 NS
8	23 July	Between Corbet – kobonila	Burnt pine	1300	5 NS
9	23 July	Dehigolla	Burnt pine	1201	3 NS, 1f
10	23 July	Dehigolla (next to P9)	Pine	1155	2m. 1f, 2 NS
13	25 July	Near Corbets gap	Cardamom	1250	1m, 2f, 5NS
14	25 July	Near P13	Cardamom	1300	4m, 7 NS
15	26 July	Above Tea estate near eagles crest	Disturbed cloud forest		1 NS
16	26 July	Horakanda	Do		1m, 2NS
17	2 Aug	Keena gommana	Do	838	1 NS
18	2 Aug	Keena gommana	Do	933	1NS
21	2 Aug	Keena gommana	Do	1230	1NS
22	2 Aug	Keena gommana	Cardamom	1153	1NS
23	4 Aug	Corberts gap	Cardamom	1372	2 NS
25	4 Aug	Near P24	Cardamom	1372	1f, 1NS
26	4 Aug	Do	Cardamom	1122	1m, 1NS
27	4 Aug	Near P26	Cardamom		1m, 1f, 2 NS

NS = not sexed.

Table 2
Skink species observed by various authorities at Knuckles

Lizard species	IUCN & Forest Dept. 1994	Ginige, 1994	Rathnayake *et al*, 1999	Bambaradeniya & Ekanayake, 2003	Present Study 2004 & 2005
Chalcidoseps thwaitesii	Observed	Observed	Not observed	Observed	Observed
Dasia halianus	Not observed	Not observed	Not observed	Not observed	Observed
Lankascincus deraniyagalae	Not observed	Not observed	Not observed	Not observed	Observed
L. fallax	Observed	Observed	Observed	Observed	Observed
L. gansi	Not observed	Not observed	Not observed	Not observed	Observed
L. taprobanensis	Not observed	Not observed	Not observed	Observed	Observed
L. taylori	Not observed	Not observed	Not observed	Not observed	Observed
Lygosoma punctatus	Not observed	Not observed	Not observed	Not observed	Observed
Mabuya beddomii	Not observed	Not observed	Not observed	Not observed	Observed
Mabuya carinata	Observed	Observed	Not observed	Observed	Observed
Mabuya macularius	Observed	Observed	Not observed	Observed	Observed
Nessia bipes	Not observed	Not observed	Not observed	Not observed	Observed
N. sarasinorum	Not observed	Not observed	Not observed	Not observed	Observed

Plate 6

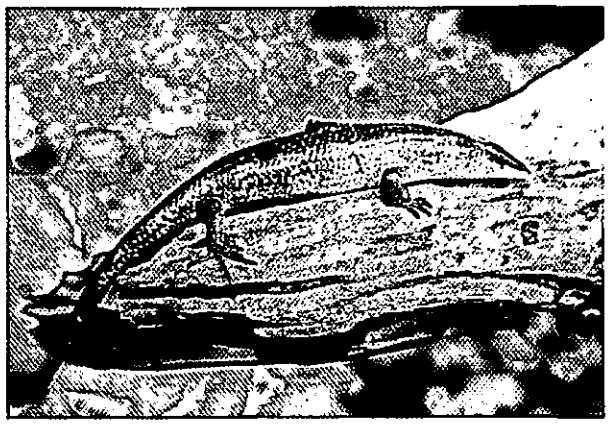


Figure 1. *Dasia halianus* (adult female)

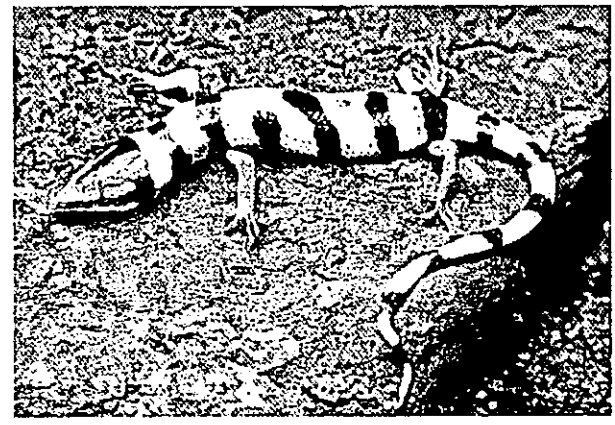


Figure 2. *Dasia halianus* (juvenile)

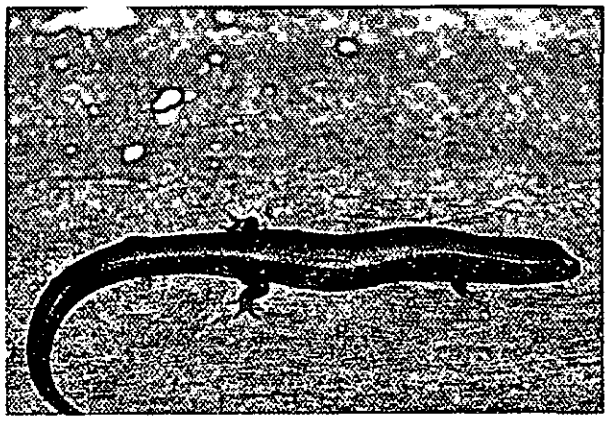


Figure 3. *Lankascincus deraniyagalae*

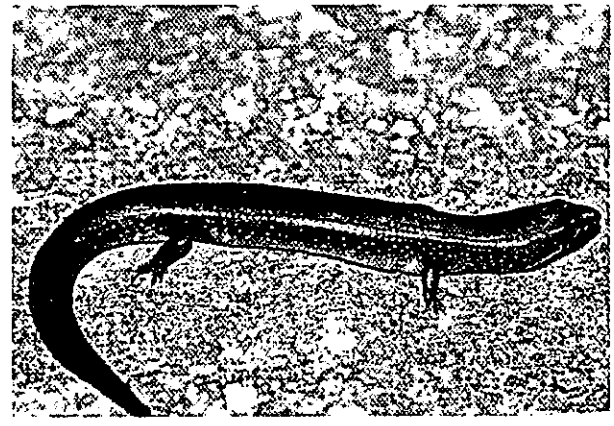


Figure 4. *Lankascincus gansi*

Figure 5. *Lankascincus taprobanensis*

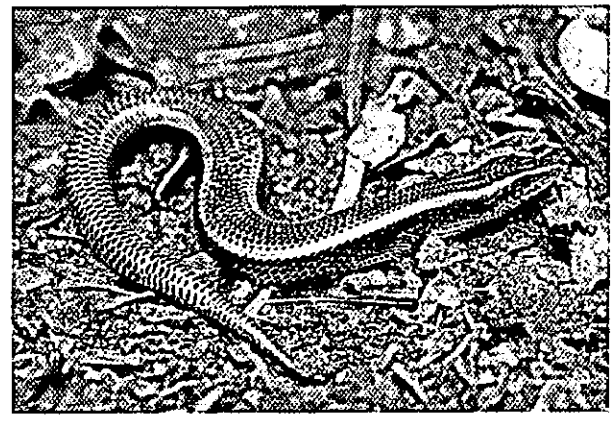


Figure 6. *Lygosoma singha*

Figure 7. *Mabuya beddomii*

Figure 8. *Mabuya macularia*

Photographs: © Suraj Goonewardene and Anslem de Silva

The Diversity of the Dumbara Mountains (The Knuckles Massif, Sri Lanka): With special reference to its herpetofauna.
Lyriocephalus Special issue, 2005 November, Volume 6 Numbers 1 & 2: 103-111
ISSN 1391-0833

CHALCIDOSEPS THWAITESII (GÜNTHER, 1872) (REPTILIA: SCINCIDAE) FOUR-TOED SKINK: PRELIMINARY OBSERVATION

Anslem de Silva[1], Aaron Bauer[2], Christopher Austin[3], Suraj Goonewardene[4], John Drake[5] & P. de Silva[1]

[1]15/1 Dolosbage road, Gampola, Sri Lanka. Email: kalds@sltnet.lk
[2]Department of Biology, Villanova University, 800 Lancaster Avenue, Villanova, Pennsylvania 19085, USA. Email: aaron.bauer@villanova.edu
[3]Museum of Natural Science, Louisiana State University, 119 Foster Hall, Baton Rouge, LA 70803 USA. Email: ccaustin@lsu.edu
[4]97, Battersea Park Road, London, SW9 4DU, UK. E-mail: hsr.wild@gmail.com (University of Edinburgh, UK)
[5]Creagard, Isle of Mull, PA75 6RA, UK. E-mail: jfdrake@gmail.com (University of Edinburgh, UK)

Keywords: *Chalcidoseps thwaitesii*, Chalcidinae, habitat, threats, Knuckles

Introduction

Chalcidoseps thwaitesii (Plate 7 Figures 1 & 2) is a geographical relict species that is mainly confined to the Knuckles Massif. It is a monotypic genus, placed in the scincid sub-family Acontinae by Deraniyagala (1931), but subsequently moved to the Scincinae by Greer (1970). Most recently, Greer and Shea (2001) have considered *Chalcidoseps* to exhibit the "chalcidine" head scale pattern, implying a possible relationship with a group of scincines that includes the majority of reduced limb forms. Relationships of *Chalcidoseps* within the Scincinae or "Chalcidinae" remain undetermined, although similarities with *Ateuchosaurus* and *Sepsophis* in head scale morphology has long been recognized (Stejneger 1907; Greer and Shea 2001).

Chalcidoseps thwaitesii was first described in 1872 by Albert Günther as *Nessia thwaitesii* from a single specimen sent to the British Museum. Except for brief morphological features reported by Deraniyagala (1931, 1953) and Smith (1935) nothing is known of its ecology, conservation status or distribution. Thus, we report for the first time some observations on the ecology of this unique skink observed during 23rd June to 25th August, 2004 and 14th July to 30th September 2005, nearly five months of field work in the Knuckles Massif during "Project Knuckles Expedition" and a series of brief visits by one of the team members (AdS) during the past 20 years.

Nomenclature

Family: Scincidae
Genus: *Chalcidoseps* Boulenger 1887.
Chalcidoseps thwaitesii (Günther, 1872). English: Four-toed skink, Sinhala: Caturanguli sarpiyahikanala. Status: Endemic.

Field methods

The field techniques adopted to study this subfossorial reptile were: 40 large leaf litter quadrats measuring 20m x 20m spanning different vegetation habitats were investigated (see de Silva, *et al.*, 2005a in this volume). Patch sampling and visual encounter studies were also conducted. Patch sampling was found to be a more effective field method for discovering this animal because of its association with certain habitats. When an animal was detected, the temperature of the microhabitat, atmospheric temperature and the body temperature were recorded using a digital thermometer (130 mm stainless steel sensor probe model ST-9263A/B/C).
Soil hardness at the point of capture was also measured using a penetrometer (pocket penetrometer model-STCL-3, measurements in kg/sq.cm). Stool samples were collected directly into sterile plastic containers containing 10% formaldehyde solution. The containers were numbered and sent for

laboratory investigations to the parasitological section of the Faculty of Veterinary Studies, University of Peradeniya. Individual animals were investigated for any physical anomalies or damage and also for any external parasites. For females, reproductive status — gravid or not, was noted. After taking morphometric measurements, identifying the gender and photographing the animals they were released at the point of capture.

Results

Morphometry

A total of 88 Specimens of *Chalcidoseps thwaitesii* were observed. Of which 15(17%) were adult male, 29 (33%) were adult female, 31 (35.2%) were unsexed adults and 13(14.8%) were juveniles. 10 of the 31(32%) were gravid.

The following measurements were recorded from a few of those specimens (Figure 1 A and B).

Figure 1- A

Box plots showing Adult Male (n=12 mean=113.17mm St D=23.34, Range 57-137mm) and Female(n=23 mean=113.65mm St D=22.15, Range 71-159mm) and Unsexed juveniles (n=7 mean=72mm St D=11.69, Range 59-92mm) total length in millimeters.

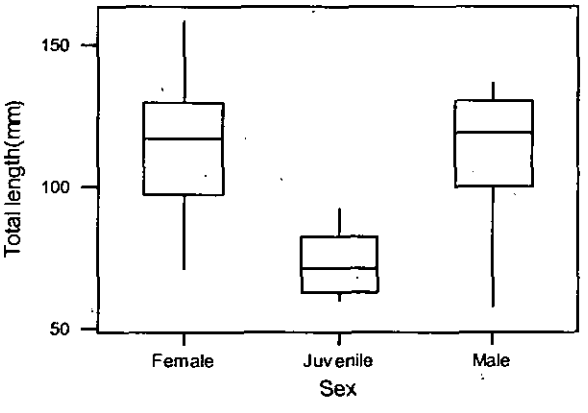
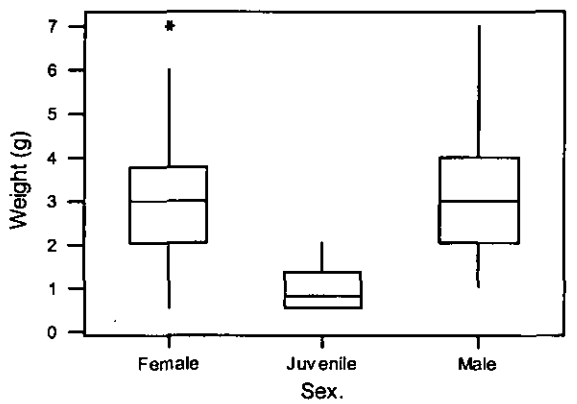


Figure 1- B
Boxplots showing Adult Male (n=11 mean=3.18g St D=1.662, Range 1.0-7.0g) and Female(n=17 mean=3.0g St D=1.640, Range 0.5-7.0g) and Unsexed juveniles (n=6, mean=0.95g St D=0.58, Range 0.5-2.0g) Weight in grams.



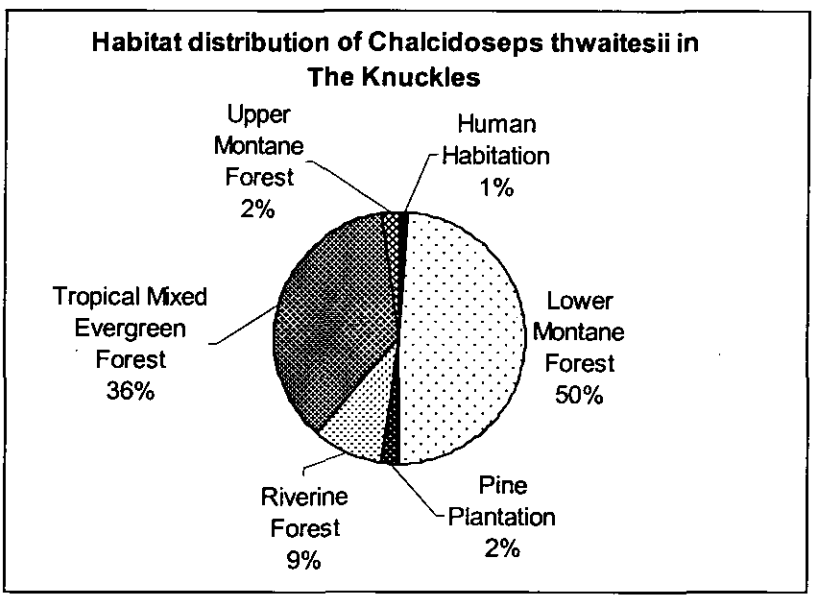
The difference was not significant between the total length of males and females (Two sample T-test, T-Value = 0.06 P-Value = 0.952 DF = 33). The difference was not significant between the weight of males and females (T-Value = 0.26 P-Value = 0.795 DF = 26)

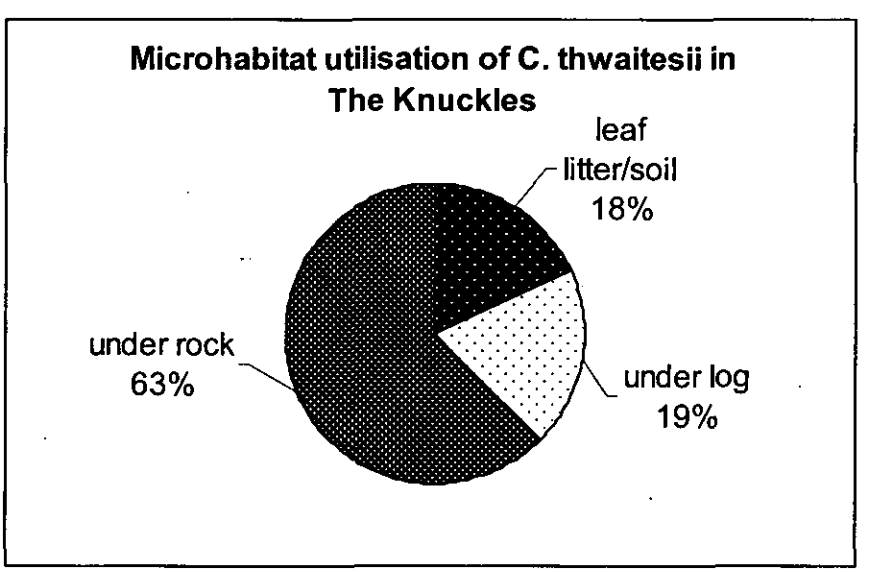
Deraniyagala (1932) reports the following measurements for an unsexed specimen: total length 107 mm of which the tail was 44 mm. A juvenile captured in July was found to have a snout to vent length of 35 mm and tail 32 mm (Deraniyagala, 1932).

Habitat and Distribution

Chalcidoseps thwaitesii is a subfossorial / fossorial animal confined to montane cloud forests, sub-montane forests, monsoon forests and riverine forests with closed canopy within the Knuckles Massif (Plate 7 Figure 3). These reptiles have also been observed in home gardens and in monoculture plantations (*Pinus carebea* and cardamom (*Ellettaria cardomomum*) within the Knuckles ecosystem (Plate 1 Figure 7). The reptile's microhabitat was comprised of rocks, boulders, decaying logs, stone heaps and damp leaf litter with cool humus underneath.

Usually, on first exposure, they were found to be either under rocks or logs as opposed to within the humus layer. A single adult was observed among the root system of a small tree on a steep bank of about 45 degrees in inclination. In 55 out of 88 observations (63%), *Chalcidoseps thwaitesii* was located underneath rocks. Logs (19%)and leaf litter/soil (18%) were the next most common cover items used (Plate 7. Figure 4). However, rocks are the most commonly available cover items in the places where *Chalcidoseps thwaitesii* is usually found. Therefore, it does not follow that these skinks are selectively using rocks as sheltering sites. Of the 40 forest floor plots investigated (de Silva *et al*, 2005a), 21 specimens of *Chalcidoseps thwaitesii* were observed in eleven plots .


Habitat distribution of Chalcidoseps thwaitesii in The Knuckles
Upper Montane Forest 2%
Human Habitation 1%
Tropical Mixed Evergreen Forest 36%
Lower Montane Forest 50%
Riverine Forest 9%
Pine Plantation 2%

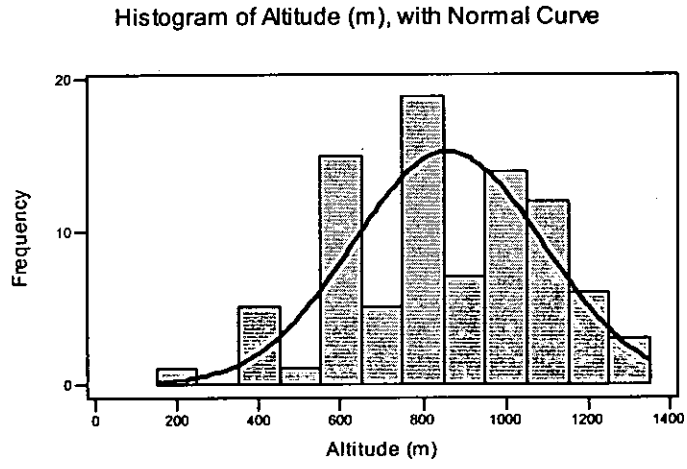

Microhabitat utilisation of C. thwaitesii in The Knuckles
leaf litter/soil 18%
under rock 63%
under log 19%

During investigations, the daytime air temperature 1.5 m above ground level in these habitats ranged from 20 to 30° C (June – August 2004 and July to September 2005). The ambient temperature in the microhabitats ranged from 0.5 to 6 ° C less than the atmospheric temperature. This was probably due to shading from the forest canopy and the moist nature of the leaf litter.

The hardness of the soil was measured using the penetrometer (pocket penetrometer model-STCL-3). The readings ranged from *mean* = 1.24±0.8, *range* = 0.25 – 3.00, *n* = 36 per kg/sq.cm. However, random checks of the earth's hardness taken where *C. thwaitesii* was not observed, ranged from 2 to 6 per kg/sq.cm.

Chalcidoseps thwaitesii is widely distributed in the Knuckles Massif, specimens were observed at: Bambugala (821m), Corbet's Gap (688m), Dehigolla (1153m), Dumbanigala (1049m), Gammaduwa (940m), Horakanda (1043m), Hunnasgiriya

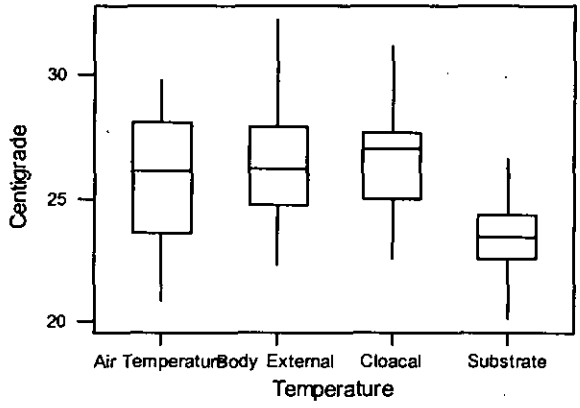
(836m), Rambukoluwa (242m), Sphinx Rock (1313m) and Yahangala (770m).



***Altitude mean* = 859.7m ± 230.4, *range* = 242.0 – 1325m, *n* = 88**

Pitawala forest (1000m), Kobonila (Loolwatte), Lakegala, Kaikawela, near Mimure, Gammaduwa, Maningala, around Nitro cave, in some parts of the Victoria Randenigala Rantambe Sanctuary and at Nagalla. Ginige (1994) records it from Kalupahana and Rattota. The altitudes at which the species were observed ranged from 590m to 1000m. However, Günther's (1872) record of a *Chalcidoseps thwaitesii* near Peradeniya, which is outside of the Knuckles Massif, needs to be confirmed for its accuracy. Ferguson (1877) considered this locality to be a mistake and suggested that the particular specimen would have come from the "direction of Raja Singha forest"

(King Raja Singha was hiding inside a forest in the Knuckles massif). Günther (1872) described the species from a single specimen sent by Dr. Thwaites, Director of the Peradeniya Botanical Gardens. However, it is well known that Dr. Thwaites had good collectors and that these workers collected many biological specimens from the Knuckles. Thus, it is possible that his collectors would also have collected the particular specimen of *Chalcidoseps* from the Knuckles since Dr. Thwaites labourers were known to collect reptiles and amphibians. Deraniyagala (1953), possibly assuming that Günther's (1872) record was accurate, reported that *Chalcidoseps thwaitesii* was rare at Kandy.



The Air temperature; *mean* = 25.8±2.5, *range* = 20.8 – 29.8, *n* = 55 and the Microhabitat temperature; *mean* = 23.7±2.4, *range* = 20.1 – 34.5, *n* = 41. The differences in means is significant with *Analysis of Variance* giving *F* (1,94) = 17.23, *p* = 0.000.

Table 1
Distribution of *Chalcidoseps thwaitesii* within the leaf litter plots in Knuckles ecosystem: Knuckles Expedition, 2004.

Plot No	Location	Habitat	Number observed
7	Near Mimure	Monsoon forest	1male. 1female
13	Near Corbett's gap	Cardamom	2 Not sexed
16	Horakanda	Cardamom	1 Not sexed
22	Horakanda	Cardamom	3 Not sexed
32		Riverine	4 Not sexed
33		Riverine	1female, 1 Not sexed
34	Road to Mimure	Riverine	2 Not sexed
35	Road to Mimure	Riverine	1female
37			1 male 1 female
38		Monsoon forest	1 Not sexed
40		Monsoon forest	1 Not sexed

Behaviour

Chalcidoseps thwaitesii is a diurnal reptile (AdS, personal observations), in contrast to the statement by Crusz & Daundasekera (1988) that "they are most active at night". Captive specimens have been observed to be active in the early morning from around 0600 hours. (AdS, personal observations)

When *Chalcidoseps thwaitesii* are exposed either by lifting logs and stones, they are very quick to slither away and creep into loose humus, soil, leaf litter or under stones, crevices, holes in the earth and among root systems. They move primarily by sinusoidal wriggling movements, rather than by using their short four-toed limbs. The snout, which is covered with a large thick rostral scale is used to burrow into loose soil or humus. When first handled some may bite and wriggle in an attempt to escape. A few feign death. Monsoon forests showed a particularly high density of individuals and are thus probably the preferred microhabitat of this species.

On five occasions, specimens were observed within close proximity of one another, several as close as 2 to 5cm beneath the same rock. In an area of 8 sq meters, 4 specimens were observed under stones between 1 and 2 meters apart. Under captivity, *Chalcidoseps*

thwaitesii was seen to attack and chase the common skink (*Lankascincus* species) when introduced to its cage. This suggest that *Chalcidoseps* is aggressive.

Invertebrates observed in the same microhabitat were Scorpion, ants, white termites (twice), pill bugs, spiders (observed twice), a crab under same log, spiders and Beetle larva. Sympatric vertebrates were *Lankascincus fallax* (twice), *Ramanella obscura*.

Food

It is believed that this species feeds on insects. In many of the places where *Chalcidoseps thwaitesii* was observed, termite mounds, or termites (inside decaying logs or in the surrounding leaf litter) were found nearby. In captivity this species readily accepted termites for feeding. Termites have often been identified as critical items in the diets of reduced-limbed skinks in many different habitat types (Huey *et al.* 1974).

Reproduction

During our investigations in July and August, three gravid females (measuring 13.1 to 15.9 mm) were found as well as two eggs. Eggs were also found in September. Few hatchlings were observed in June, July and August. Deraniyagala (1953) reported two soft shelled eggs collected in April from Gammaduwa. He described them as being somewhat kidney shaped with one end slightly more pointed than the other. They measured 18 x 6 mm and 18 x 11 mm and had been deposited in loose dark loamy soil in a cardamom plantation.

Internal and external Parasites

Two specimens *Chalcidoseps thwaitesii* were observed with chiggers and mites. One specimen from a riverine forest was also observed to have mites. During the present study, we observed two infected with nematode larvae (see de Silva *et al.*, 2005b in this volume). Crusz & Daundasekera (1988) identified the helminth *Meteterakis sinharajensis* and the nematode *Paraphayngodon adamsoni* from the large intestine of a *Chalcidoseps thwaitesii* from Nagalla (Gammaduwa).

Present status, threats, and recommendations

The tails of all (except one) of the observed *Chalcidoseps thwaitesii* were intact, whereas many other species of skinks and geckos observed in the Knuckles and elsewhere had regenerated tails. Furthermore, all the specimens of *Chalcidoseps thwaitesii* observed appeared physically healthy. During the survey, we made observations on nearly 88 specimens, with minimal search effort, suggesting that population densities are substantial, at least in the areas of the Knuckles ecosystem surveyed. This substantiates Wilcox's (1980) hypothesis that the reptiles are less extinction-prone than other vertebrates. Earlier reports considered the species to be rare (Ginige, 1994) and they were described as being "few in the range and fragmented" (de Silva *et al.*, 2000). The CAMP report, which assessed this reptile using IUCN Red List criteria, ranked it as Endangered (de Silva *et al.*, 2000). The 1999 National list of threatened animals ranked it as Threatened (IUCN, Sri Lanka, 2000).

In the Knuckles Massif, forest has been increasingly cleared for agriculture, housing, hotels and other development activity. Furthermore, most villagers living adjacent to the Knuckles conservation area keep poultry and cats. Studies show that domestic poultry and cats feed extensively on skinks, geckos, agamids and snakes (de Silva, 2001). During the present study, we observed that several endemic agamids, geckos, skinks, and snakes inhabited village houses and compounds. A study at Nilgala (de Silva *et. al.* 2004, Goonewardene *et al.* 2004) and a survey on the "Knowledge Attitude and Practice" of inhabitants in Mimure showed that a large number of reptiles were eaten by domestic poultry and cats (de Silva *et al.*, 2005c in this volume). Thus, we see that domestic poultry and cats pose a major threat to the unique relict reptiles that are exclusive to Knuckles. Habitat fragmentation is also a threat. The natural forests of the Knuckles Massif are severely fragmented due to human activities. Soil moisture and resulting cooler temperatures are two important habitat requirements of this skink. In isolated forest patches moisture and temperature is highly variable and this

variation may be detrimental to survival and/or reproduction of *Chalcidoseps thwaitesii* in forest fragments. It was observed that when *Chalcidoseps thwaitesii* was kept out from their niche for 10 to 15 minutes their skin started to dry and then shriveled. Thus, the coolness and moisture of its microhabitat appear to be critical factors for the survival of *Chalcidoseps thwaitesii*. Furthermore, studies on the annual rainfall of the Knuckles Range have shown a recent decrease in the rainfall (Giragama & Madduma Bandara, 1993). This could have a detrimental impact on the reptiles, amphibians and other animals inhabiting the smaller more fragmented forest patches. Animals also tend to fall easy victim to predators in these areas because they are more exposed. Therefore, it is important that the authorities declare a wider buffer zone around the Knuckles conservation area. Steps should also be taken to educate the local farmers in order to discourage the use of insecticides in the buffer zone, as this may be having a detrimental impact on insect prey species. Although there is no data regarding the direct toxic effects of pesticides on amphibians and reptiles, but for humans it has become a leading cause of death in Sri Lanka. Furthermore, farmers in Sri Lanka use 77-124 Kg of nitrogen fertilizer per hectare, which is 2 to 8 times more fertilizer than is used in any other country in the region (Baldwin, 1991). Although there is no data regarding the direct toxic effects of pesticides on amphibians and reptiles, increased pesticide use has become a leading cause of human deaths in Sri Lanka.

Acknowledgements

We wish to thank: Mr. Sarath Fernando, Conservator General, of the Forest Department for permission granted to (AdS, AB and CA) (FRC/5 and FRC/6). The Director General, of the Department of Wildlife Conservation and Mr. H. D. Rathnayake for approvals (WL/3/2/1/14/12). The Forest Department officers at Loolwatte and Illukkumbura for their friendly support throughout the study.

University of Edinburgh, United Kingdom for funding and supporting Project Knuckles 2004 an undergraduate research expedition (especial thanks the following University of Edinburgh Funds: Aranmore Memorial Traveling Scholarship, Davis Fund, James Rennie Bequest, Student Travel Fund, Weir Fund, William Dickson Traveling Fund and also British Student Travel Fund, Edinburgh No 2 Fund, Gilchrist Educational Trust, Lindeth Charitable Trust, Peoples Trust for Endangered Species, Royal Geographical Society Expedition Research Grant (Gumby Award).

We also thank Alasdair Ford, Andrew Burns, Douglas Fraser, Laura Packham and Polly Bramham from the Project Knuckles 2004 for helping to gather data in the field.

Aaron Bauer was supported by funds from the Department of Biology at Villanova University. This research was funded in part by National Science Foundation grants DEB 0445213 and DBI 0400797 to CCA as well as by a Louisiana State University Faculty Research grant.

Literature cited

BALDWIN, M. F. (Ed.). 1991. *Natural Resources of Sri Lanka Conditions and Trends.* NARESA, Colombo, 280 pp.

CRUSZ H. & D.M. A. K. DAUNDASEKERA. 1988. Parasites of the relict fauna of Ceylon. ix Helminths from burrowing scincine lizards. *Ann. Parasitol. Hum. Comp. Paris* 63(6): 439-447.

DE SILVA, ANSLEM., S. MOLUR & S. WALKER. 2000. *Conservation Assessment and Management Plan CAMP Report for amphibians and selected taxa of reptiles of Sri Lanka.* Conservation Breeding Specialist Group, Sri Lanka. 226 pp.

DE SILVA, ANSLEM. 2001. *The Herpetofauna of Sri Lanka: historical aspects and current status.* Ministry of Environment, 100 pp + 150 plates .ISBN 955-96005-0-8

DE SILVA, ANSLEM, A. BAUER, C. C. AUSTIN, B.J.K. PERERA, R.L.JAYARATNE, M. sGOONASEKERA, S. GOONAWARDENA, Z. HAWKE, V. VANNECK & A. DRION. 2004. Some cultural traits of the inhabitants of the Nilgala fire savannah, Sri Lanka, towards animals: with special reference to the herpetofauna. IN: *The herpetology of Sri Lanka: current research (Including the Proceedings of*

the Fourth World Congress of Herpetology, December 2001 and Nilgala Expedition, 2003). *Lyriocephalus* special edition. 2004. Volume 5 (1 & 2): 183-191.

de Silva, Anslem., S. Goonewardene, J. Drake, P. de Silva, R.D.C.S.K.Dasanayaka, A. M. R. K. Amarakoon & M. M. Goonasekera. 2005a. Species diversity and richness of the herpetofauna in large leaf litter plots in the Knuckles ecosystem. *Lyriocephalus* Special issue, Volume 6 Numbers 1 & 2:

de Silva, Anslem., R. P. V. J. Rajapaksa, R.R.M.K.K. Wijesundera, M. de Silva, A. Bauer, S.Goonewardene, J. Drake, C.C. Austin, N. A. N. D. Perera, D. de Silva, U. Hemachandra , C. Nelawatura & D. A. Sathrasinghe. 2005b. Preliminary observations on some parasites of geckos, skinks and snakes inhabiting the Knuckles massif. *Lyriocephalus* Special issue, Volume 6 Numbers 1 & 2:

de Silva, Anslem., A. Bauer, S. Goonewardene, J. Drake, G. S. Samarawickrama & M. M. Goonasekera. 2005c. Some cultural traits and attitudes of the inhabitants of Mimure (in the Knuckles massif) towards local animals, with special reference to the herpetofauna. *Lyriocephalus* Special issue, Volume 6 Numbers 1 & 2:

DERANIYAGALA. P.E. P. 1931. Some Ceylon lizards. *Spolia Zeylanica* 16(2): 139-180

DERANIYAGALA, P. E. P. 1932. Reproduction of *Acontias (Nessia) Layardi. Spolia Zeylanica* 17(1): 47-49.

DERANIYAGALA, P. E. P. 1953. *A Colored atlas of some vertebrates from Ceylon, Vol.2, Tetrapod reptilia.* Ceylon National Museum, 101 pp.

FERGUSON, W. 1877. *Reptile fauna of Ceylon. Letter on collection sent to the Colombo museum.* Government Printer, Colombo 42 pp. (include brief notes on Agamids, Geckos and Skinks)

GINIGE, P. 1994. Reptile fauna of the Knuckles Range, Sri Lanka. *Lyriocephalus* 1(1&2): 38-43.

GIRAGAMA, W. M. G. B. & C. M. MADDUMA BANDARA. 1993. Rainfall and relative humidity of the Dumbara Hills (Knuckles Range). *Annual Review 1992,* Institute of Fundamental Studies, Kandy, pp.72-73.

GOONEWARDENE, S., Z. HAWKW, V. VANNECK, A. DRION, ANSLEM DE SILVA, R. JAYARATNE & J. PERERA. 2004. *Report of Project Hoona – 2003. Diversity of Nilgala fire savannah, Sri Lanka: with special reference to its herpetofauna.* Project Hoona. 81 pp + 164 – 220 pp.

GREER, A. E., Jr. 1970. A subfamilial classification of scincid lizards. *Bulletin of the Museum of Comparative Zoology* 139(3):151-184.

GREER, A. E., Jr. & G. SHEA. 2001. Origin and evolution of the parthenogenetic lizards, *Cnemidophorus maslini* and *C. cozumela. Journal of Herpetology* 34(4): 634-637.

GÜNTHER, A. 1872. Descriptions of some Ceylonese reptiles and batrachians. *Annals & Magazine Natural History.* London. 4(9): 85-88

HUEY, R.B., E.R. PIANKA, M.E. EGAN, AND L.W. COONS. 1974. Ecological shifts in sympatry: Kalahari fossorial lizards (*Typhlosaurus*). *Ecology* 55: 304-316.

IUCN SRI LANKA. 2000. *The 1999 list of threatened fauna and flora of Sri Lanka.* Colombo: IUCN Sri Lanka. 114 pp

SMITH, M. A. 1935. *The fauna of British India, including Ceylon and Burma. Reptilia & Amphibia. Vol. 11- Sauria.* Taylor & Francis, London. 440 pp.

STEJNEGER, L. 1907. Herpetology of Japan and Adjacent Territory. *Bulletin of the United States National Museum* 58: 1-557.

WILCOX, B. A. 1980. Insular ecology and conservation. In: *Conservation biology, an evolutionary-ecological perspective* (Eds.) Souli, M.E. & B. A.Wilcox. 95-117. Sunderland, M.A. Sinauer Associates.

Plate 7

Figure 1. *Chalcidoseps thwaitesii*

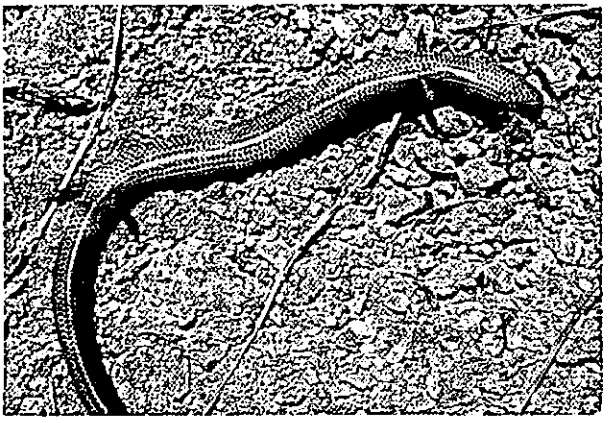


Figure 2. Early gravid *C. thwaitesii*

Figure 3. Habitat tropical mixed evergreen forest

Figure 4. Microhabitat stone heaps

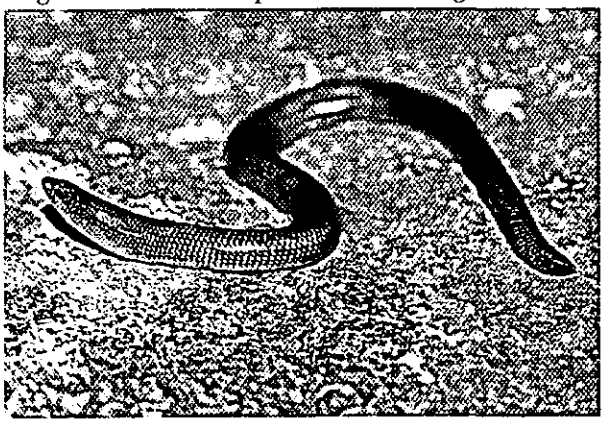


Figure 5. *Nessia bipes*

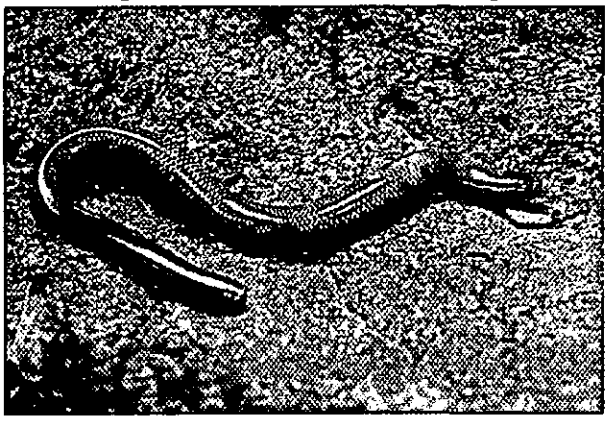


Figure 6. *Nessia sarasinorum*

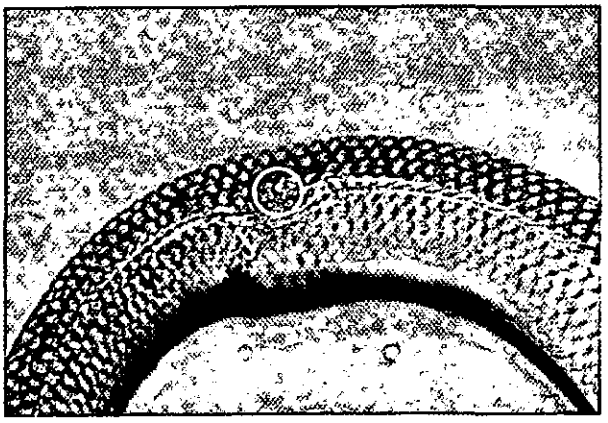


Figure 7. Bud like hind limb

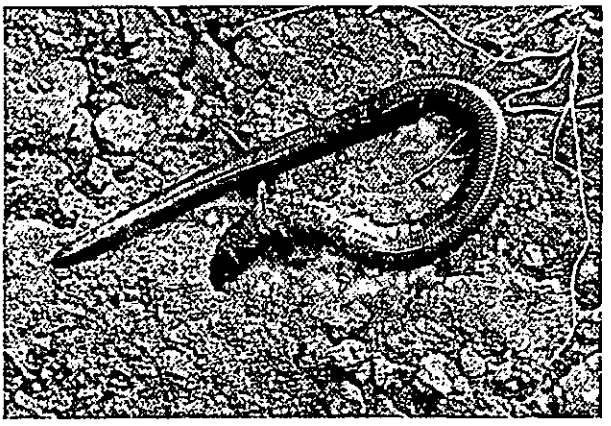


Figure 8. Killed *N. sarasinorum*

Photographs: © Suraj Goonewardene and Anslem de Silva

The Diversity of the Dumbara Mountains (The Knuckles Massif, Sri Lanka): With special reference to its herpetofauna.
Lyriocephalus Special issue, 2005 November, Volume 6 Numbers 1 & 2: 115-123
ISSN 1391–0833

NOTES ON *NESSIA* SPECIES INHABITING THE KNUCKLES MASSIF WITH SPECIAL REFERENCE TO *NESSIA BIPES* SMITH, 1935 (REPTILIA: SCINCIDAE): THE DOMINANT SNAKE SKINK

Anslem de Silva[1], A. Bauer[2], C. C. Austin[3], S. Goonewardene[4] , J. Drake[4], A. Balasubramaniam[5], C. Rajendran[5], V. Pathmadevan[5], M. Fernando[6] & K.Sureskumar[6]

[1]15/1 Dolosbage road, Gampola, Sri Lanka. Email: kalds@sltnet.lk
[2]Department of Biology, Villanova University, 800 Lancaster Avenue, Villanova, Pennsylvania 19085, USA. Email: aaron.bauer@villanova.edu
[3]Museum of Natural Science, Louisiana State University, 119 Foster Hall, Baton Rouge, LA 70803 USA. Email: ccaustin@lsu.edu
[4]97, Battersea Park Road, London, SW9 4DU, UK. E-mail: hsr.wild@gmail.com (University of Edinburgh, UK)
[4]Creagard, Isle of Mull, PA75 6RA, UK. E-mail: jfdrake@gmail.com (University of Edinburgh, UK)
[5]University of Jaffna, Sri Lanka [6] University of Eastern Sri Lanka (Chenkaladi)

Keywords: *Nessia bipes, Nessia sarasinorum,* Scincinae, Chalcidinae, Knuckles

Introduction

The genus *Nessia* was placed in the scincid sub-family Acontinae by Deraniyagala (1931), but subsequently moved to the Scincinae by Greer (1970), who recognized eight species, all endemic to Sri Lanka (Das & de Silva, 2005; Deraniyagala 1931, 1953a, 1953b, 1953c; de Silva 2001). Based on morphological data, *Nessia* is presumed to be monophyletic. Its affinities with other scincid genera have been the subject of much speculation in the past (e.g., Boulenger 1887; Hewitt 1929; Deraniyagala 1931; Smith 1935) but most recently Greer and Shea (2001) have considered *Nessia* to exhibit the "chalcidine" head scale pattern, implying a possible relationship with a group of scincines that includes the majority of reduced limbed forms. Relationships of *Nessia* within the Scincinae or "Chalcidinae", however, remain uncertain.

Except for few brief accounts by Deraniyagala (1931, 1953a, 1953b, 1953c), Smith (1935) and Taylor (1950) nothing has been published on the ecology of *Nessia* species to date. Gans (1995) recorded distribution localities of six species of *Nessia*. The present paper provides additional brief notes on the ecology and natural history of *Nessia bipes* Smith, 1935 and *Nessia sarasinorum* Müller, 1889 (Plate 7. Figures 5 & 6) as observed during the Knuckles Expedition, 2004 and 2005. Our preliminary data highlight the need for future studies to understand the ecology, natural history, and conservation status of these poorly known lizards.

Field methods

Two field techniques were used to investigate this subfossorial reptile: sampling of large leaf litter quadrats measuring 20m x 20m (see de Silva, *et al* 2005a this volume) and Patch sampling. Patch sampling was found to be a more effective field method for discovering this animal because of its tendency to occur in certain types of habitat. When caught, individuals were examined for abnormalities, damage, and any external parasites. For females, reproductive status was noted. For a subset of individuals morphometric measurements were taken to examine morphological variation. After photographing, the animals were released back at the same locality where they were found.

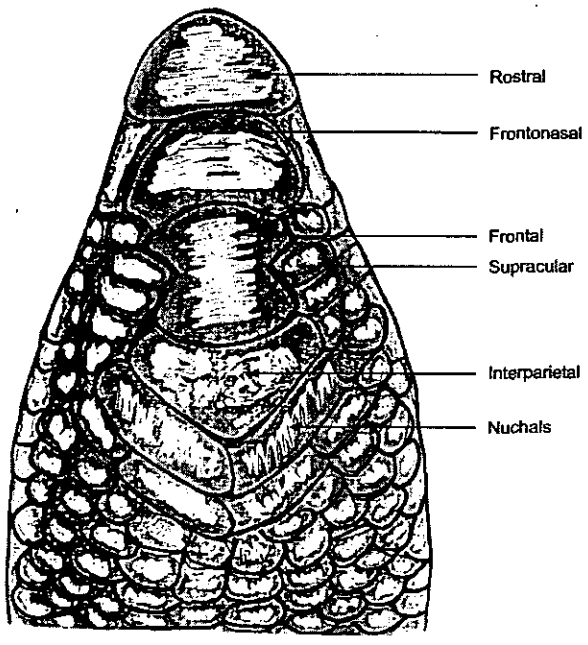
Results

Identification

Nessia bipes can be distinguished from other *Nessia* species in having rudimentary bud-like pair of posterior limbs surrounded by

small scales situated on either side the cloacae (Plate 7. Figure 7). The scale rows at mid body are 26 to 28 and the interparietal broader than frontal. Also an overlying mark on the interparietal was observed in *N. bipes* possibly it has a parietal foramen (Figure 1). Whereas in *Nessia sarasinorum* the scale rows at mid body are 22 and the interparietal is narrower than frontal (Figure 1). In both species although well-developed forelimbs are not present, slight bulges in the pectoral region surrounded by small scales signal their position.

Figure 1
Head scalation of *Nessia bipes*



Morphometry

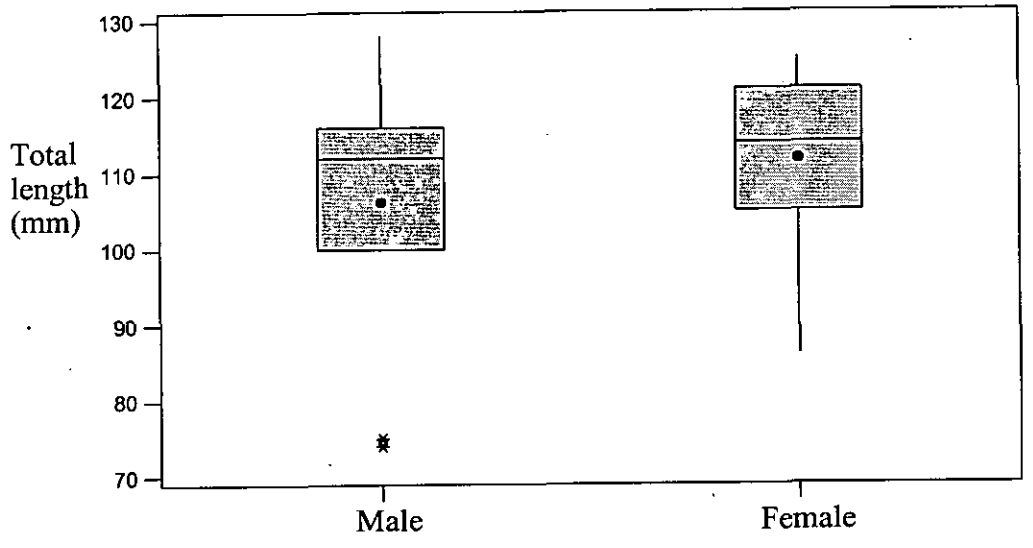
Nearly 50 specimens of *Nessia bipes* were observed from various localities in the Knuckles Massif. However, details such as measurements, gender, status etc. were recorded only of 41 specimens of *Nessia bipes,* of which 14 were male adults, 9 were female adults, 16 unsexed adults and 2 juveniles. Furthermore 5 specimens of *Nessia sarasinorum* (Plate 7. Figure 6) were observed at Yahangala (300m) of which 1 was male adult, 1 was female adult and 3 unsexed adults

The total lengths of Adult Male *Nessia bipes* (n=11 mean=106.27mm St D=17.08, Range 74-128) and Female (n = 7 mean = 111.71mm St D=13.01, Range 86-125mm) were not significant (T-Value = -0.72 P-Value = 0.483 DF = 16) (Figure.2).

Similarly comparing the weights of adult male (n=9 mean=2.26g St D=0.38, Range 2.0-3.1g) and female (n=7 mean=1.7g St D=0.70, Range 1.0-2.7g) were not significant (T-Value = -2.03 P-Value = 0.062 DF = 14) (Figure.3).

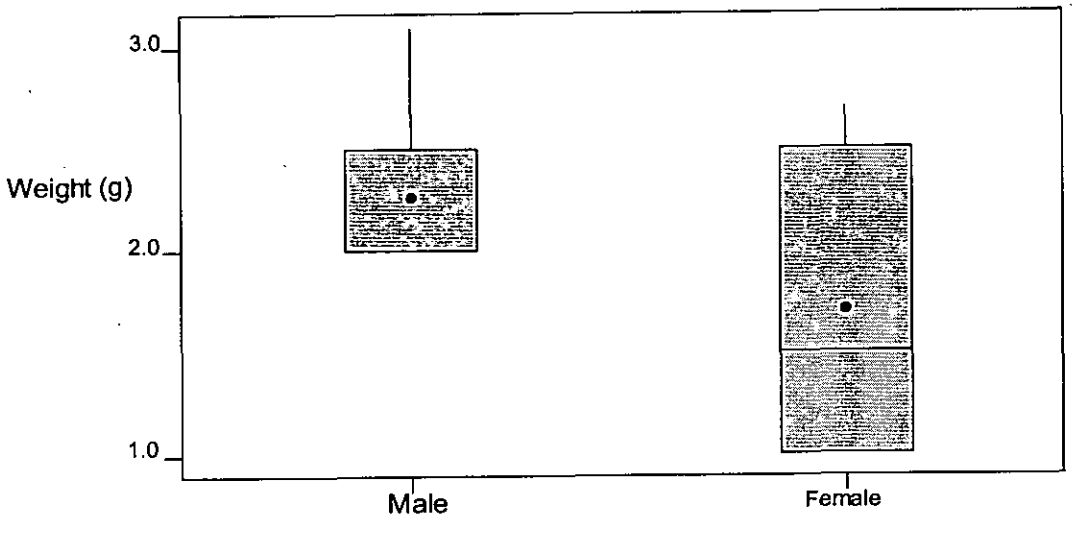
Deraniyagala (1932) reported the following measurements for an unsexed specimen: Total length 107 mm of which the tail was 44 mm and a juvenile, caught in July was also measured: snout to vent 35 mm and tail 32 mm.

Figure 2
Total length of adult Male and Female *Nessia bipes*
(in mm)



Total length (mm) indicated by solid circles

Figure 3
Weights of adult Male and Female *Nessia bipes*
(in grams)



The weights (g) indicated by solid circles

Habitat and Distribution

Nessia bipes were inhabiting a wide range of habitats such as: Lowland dry semi-evergreen forests, Mild-elevational wet semi- evergreen forests, Mild-elevational dry-evergreen forests, Montane wet-elevational forests (Cloud forest) and plantations (e.g. cardamom, *Acacia*) and home gardens within the Knuckles Range. However, we also observed them to be common in disturbed forests of the Knuckles Massif. They utilized microhabitats beneath rocks/boulders, decaying logs and within the leaf litter. *Nessia bipes* were often found underneath rocks and boulders. A similar pattern was observed in the sympatric skink *Chalcidoseps thwaitesii*. The air temperature (1.5 m above the ground) in these habitats ranged from 24 to about 30 °C during the day (June – August 2004 and July to September 2005). Figure 6 indicate the differences in temperature between air and microhabitat temperature, showing means by solid circles. The air temperature; mean = 24.8±2.6 (range = 21.1 – 29.1, n = 25) and the microhabitat temperature; mean = 22.8±1.4 (range = 20.0 – 25.8, n = 19). The differences in means was significant with Analysis of Variance giving F (1, 42) = 8.97 P=0.005, suggesting that the ambient temperature within the selected microhabitat was less than the atmospheric temperature of the forest and the relative humidity ranged from 63 % to 78%. The Penetrometer reading of the microhabitat mean was 1.06±0.61 (range = 0.25 – 2.00, n = 18).

The forest floor quadrat studies (de Silva *et al* 2005a this volume), showed that seven specimens of *Nessia bipes* were observed within four plots (Table 1). Available reports and our observations suggest that *Nessia bipes* is mainly confined to the Knuckles Massif. Gans (1995) reported finding specimens in Gammaduwa and Matalipitiya. We observed the species at: Corbet's Gap (688m), Dehigolla (1095m), Gammaduwa (1115m), Illukumbura (638m), Kobonilla (1025m), Lakegala (434m), Kikawela, Karandaketiya, and Deenston. Altitudes ranged from 434.0-1115.0m (n=46 mean=823.6m St D=175.5) across these sites (Figure 7).

As regards the five *Nessia sarasinorum,* three were observed under boulders and one near a large granite boulder in humus, one was observed injured and dead while bulldozing a land for the preparation of a road. *Nessia sarasinorum* is known from a wide range of localities mainly in the dray zone plains from 80 m to 300 m above sea level (see Deraniyagala, 1953 and Gans, 1995). However, this is the first report of this relict species from the Knuckles massif. Gans (1995) considers that it inhabits in the low dry scrub jungles. However, we observed our specimens in sub montane monsoon forests. Gans (1990) also consider that *Nessia* species show restricted ranges with no overlap. Furthermore, our extensive sampling in the Knuckles range we did not observe *Nessia monodactyla*. Thus, we feel that *Nessia monodactyla* reported from the Knuckles (Bambaradeniya & Ekanayake 2003) "needs confirmation".

Figure 4

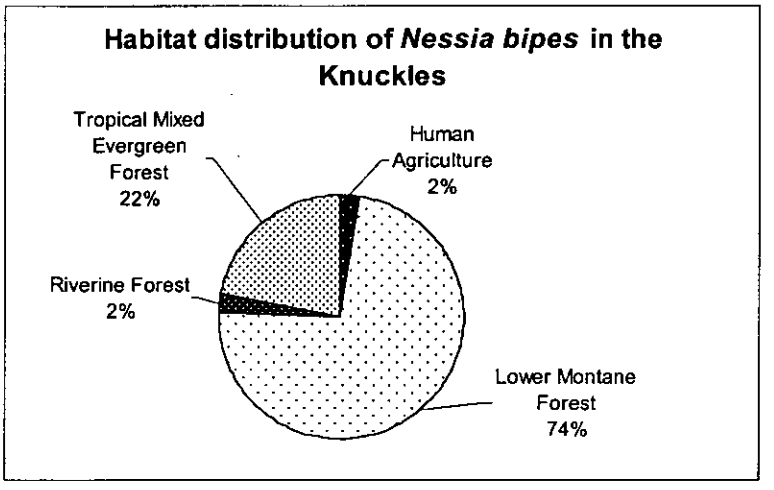


Figure 5

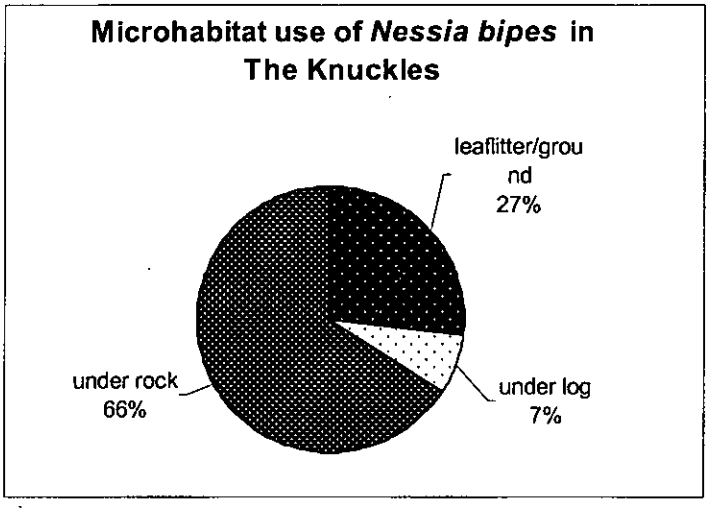


Figure 6

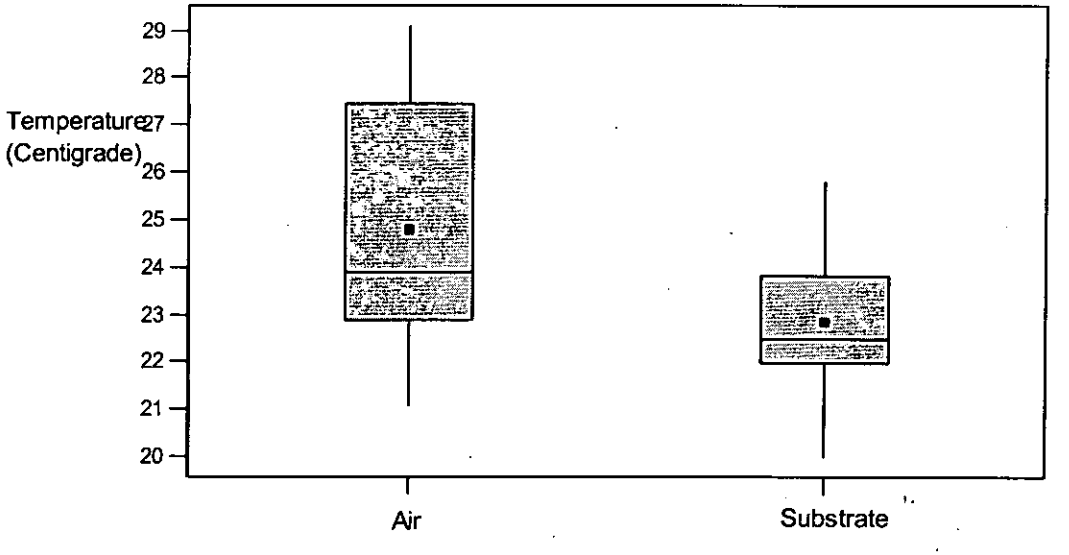


Figure 7
Altitude range of *Nessia bipes*

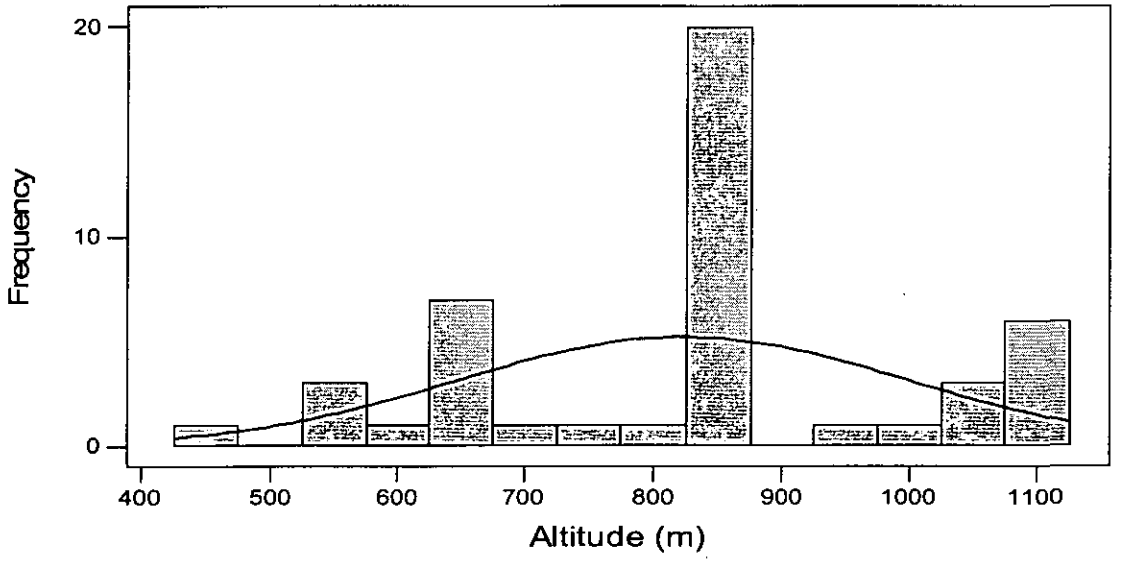


Table 1
***Nessia bipes* observed within forest leaf litter Quadrats**

Quadrat No	Location	Habitat	Altitude (m)	Number observed
7	Near Mimure	Dry Sub-Montane evergreen forests	0500	4
24	Road side near Forest office	Acacia plantation	1095	1
28	Kobonila	Dry Sub-Montane evergreen forests (fragmented)	1025	1
30	Near niter cave	Riverine forest	1065	1

Behaviour
Nessia bipes and *N. sarasinorum* are diurnal reptiles. When exposed, either by the lifting of logs, stones or leaf litter, they were quick to wriggle and hide within the loose humus, soil, leaf litter, under stones, crevices and holes in the earth. When handled some showed a tendency to bite and wriggle in order to escape. It was observed that (similar to *Chalcidoseps thwaitesii*) the skin of *Nessia* dries and shrivels within 10-15 minutes when removed from its moist habitat. Therefore, the coolness and/or moisture content of the microhabitat appear to be a critical requirement for prevention of desiccation and the survival of these reptiles. Specimens were observed together as well as close to one another suggesting possible communities. *Chalcidoseps thwaitesii*, *Lankascincus* species and *Geckoella triedra* were often observed as sympatric reptiles in the same microhabitat of *Nessia bipes*. *Otocryptis wiegmanni* and *Hypnale hypnale* too were sometimes observed on the forest floor in the same habitat. Sympatric invertebrates were termites (3 occasions), spiders, snails, ants, and beetle larva.

Food
Nessia bipes and *N. sarasinorum* feed on insects. Live specimens kept for observations readily accepted termites.

Reproduction
Gravid *Nessia bipes* with 2 eggs were observed in August and September. 2 Hatchlings (measuring 62mm, weight= 0.5g) were observed in June to September.

Deraniyagala (1953c) reported that 2 to 4 soft shelled eggs are laid in March, April and May. A female 130 mm long had laid two eggs measuring 16 x 8 lmm and had been deposited in loose dark loamy soil in a cardamom plantation.

Internal and external Parasites

We observed heavy infestation of coccidian oocysts in some *Nessia bipes* (de Silva *et al.* 2005b in this volume) and some mites (on 3 occasions). Crusz & Daundasekera (1988) have observed nematodes *Melelrakis sinharajensis* and *Parapharyngodon adamsoni* in the large intestine and rectum of *Nessia bipes*.

Present status, threats and recommendations

Nessia bipes is a common reptile in the Knuckles Range, whereas, *N. sarasinorum* is restricted to a small range in the North east Knuckles, with no overlap. However, previous reports on the Knuckles did not list this species (Bambaradeniya & Ekanayake 2003; Cooray 1998; Ginige 1994; Rathnayake *et al.*, 1999). According to IUCN Red List Criteria, *Nessia bipes* is ranked as an Endangered and *N. sarasinorum* is ranked Lower Risk near threatened (de Silva, Molur & Walker 2000). IUCN (2000) ranks *bipes* and *sarasinorum* as Threatened species. Although a major part of the Knuckles (that is above1,067 m) is declared as a conservation forest, even in the conservation area the flora and fauna face many threats due to human activities. Climatic changes over the past 100 years may also have an impact. The annual rainfall at Kobonila has decreased from 3800 mm in 1982 to 3400 mm in 1990 (Madduma Bandara 1991). In addition, the negative impacts of cardamom cultivation at the Knuckles have been extensively reported (Abeygunawardena & Vincent 1993; Gunawardane 2003). Studies have shown that in natural forested areas without cardamom cultivation the 'A' horizon is well preserved and covered with mulch to a depth of 30-35 cm whilst in cardamom fields the mulch level has been reduced to 15-25 cm (Madduma Bandara, 1991). These data are from a study conducted in the mid 1980's, when we measured the mulch level in many types of forests and plantations during the survey in 2004 and 2005, it was less than 10 cm. In addition, soil erosion was high. Thus, we can foresee long-term, irreversible habitat degradation that could negatively impact upon these and other fossorial animals that live in the humus of the forest floor. Therefore, it is important that the authorities take immediate steps to educate the cardamom cultivators in order to prevent further soil erosion and habitat degradation.

Acknowledgements

We wish to thank: Sarath Fernando, Conservator General, Forest Department for permission granted to (AdS, AB and CA) (FRC/5 and FRC/6) to conduct the above study. Director General, Department of Wildlife Conservation and H. D. Rathnayake for approval (WL/3/2/1/14/12). The Forest Department officers at Loolwatte and Illukkumbura for their friendly support throughout the study. Manel Goonasekera, Head Department of Biological Sciences, Rajarata University of Sri Lanka for her support from the inception of the project.

The University of Edinburgh, UK for funding and supporting project knuckles 2004 undergraduate research expedition (special thanks to the following University of Edinburgh Funds: Aranmore Memorial Traveling Scholarship, Davis Fund, James Rennie Bequest, Student Travel Fund, Weir Fund, William Dickson Traveling Fund and also British Student Travel Fund, Edinburgh No 2 Fund, Gilchrist Educational Trust, Lindeth Charitable Trust, Peoples Trust for Endangered Species, Royal Geographical Society Expedition Research Grant (Gumby Award). Also thanks to Alasdair Ford, Andrew Burns, Douglas Fraser, Laura Packham and Polly Bramham from Project Knuckles 2004 for helping to gather data in the field.

Aaron Bauer was supported by funds from the Department of Biology at Villanova University. USA. This research was funded in part by National Science Foundation grants DEB 0445213 and DBI 0400797 to Christopher Austin as well as by a

Louisiana State University Faculty Research grant.

Literature cited

Abeygunawrdena, P. & J. R. Vincent. 1993. Bare Knuckles: fighting deforestation in Sri Lanka. *Harvard Institute for International Development*, 1-17.

Bambaradeniya, C. N. B. & S. P. Ekanayake. 2003 *A Guide to the Biodiversity of the Knuckles Forest Region.* IUCN, Sri Lanka Country Office, Colombo. 68 pp.

Boulenger, G. A. 1887. Catalogue of the lizards in the British Museum (Natural History). 3. 595 pp.

Cooray, P. G. 1998. *The Knuckles massif – a portfolio.* Forest Department, Sri Lanka. 75 pp.

Crusz H. & D.M. A. K. Daundasekera. 1988. Parasites of the relict fauna of Ceylon. IX. Helminths from burrowing scincine lizards. *Ann. Parasitol. Hum. Comp. Paris* 63(6): 439-447.

Das, I & Anslem de Silva. 2005. *Photographic guide to snakes and other reptiles of Sri Lanka.* New Holland, UK, 144 pp.

de Silva, Anslem. 2001. *The Herpetofauna of Sri Lanka: historical aspects and current status.* Ministry of Environment, 100 pp

de Silva, Anslem. S. Molur & S. Walker. 2000. *Conservation Assessment and Management Plan CAMP Report for amphibians and selected taxa of reptiles of Sri Lanka.* Conservation Breeding Specialist Group, Sri Lanka. 226 pp.

de Silva, Anslem, A. Bauer, C. C. Austin, S. Goonewardene, J. Drake, P. de Silva, R.D.C.S.K.Dasanayaka, A. M. R. K. Amarakoon & M. M. Goonasekera. 2005. Species diversity and richness of the herpetofauna in large leaf litter plots in the knuckles ecosystem. In: *The Diversity of the Dumbara Mountains (The Knuckles Massif, Sri Lanka): With special reference to its herpetofauna. Lyriocephalus* Special issue, Volume 6 Numbers 1 & 2:

de Silva, Anslem., R. P. V. J. Rajapaksa, K. Wijesundera, M. de Silva, A. Bauer, S. Goonewardene, J. Drake, C. Austin, C. Nelawatura, D. A. Satharasinghe, D. de Silva, W. C. G. M. Jayasinghe, U. Hemachandra. 2005. Preliminary observations on some parasites of reptiles inhabiting the Knuckles massif. In: *The Diversity of the Dumbara Mountains (The Knuckles Massif, Sri Lanka): With special reference to its herpetofauna. Lyriocephalus* Special issue, Volume 6 Numbers 1 & 2:

Deraniyagala. P.E. P. 1931. Some Ceylon lizards. *Spolia Zeylanica* 16(2): 139-180.

Deraniyagala. P. E. P. 1932. Reproduction of *Acontias (Nessia) Layardi. Spolia Zeylanica* 17(1): 47-49.

Deraniyagala. P.E. P. 1953a. Limbless lizards of Ceylon. J. *Royal Asiatic Soc. (Ceylon Branch).* New Series. 3(1): 25-26

Deraniyagala. P.E. P. 1953b. Ceylon's Faunal Land Link with South Africa. *Ceylon Today.*1 (4):26.

Deraniyagala, P. E. P. 1953c. *A Colored atlas of some vertebrates from Ceylon, Vol.2, Tetrapod reptilia.* Ceylon National Museum, 101 pp.

Gans. C. 1990. Fossorial amphibians and reptiles: their distributions as environmental indicators. In: *Ecology and Landscape Management in Sri Lanka.* W. Erdelen, C. Preu, N. Ishwaran & C. M. Madduma Bandara (Eds.) pp. 189-199

Gans, C. 1995. New records of skinks from Sri Lanka. *Lyriocephalus* 2(1&2): 21-24.

Ginige, P. 1994. Reptile fauna of the Knuckles Range, Sri Lanka. *Lyriocephalus* 1(1&2): 38-43.

Greer, A. E., Jr. 1970. A subfamilial classification of scincid lizards. *Bulletin of the Museum of Comparative Zoology* 139(3):151-184.

Greer, A. E., Jr. & G. M. Shea. 2001. A major new head scale character in non-lygosomine scincid lizards. *Journal of Herpetology* 34: 629-634.

Gunawardane, H. G. 2003. Ecological implications of cardamom cultivation in the high altitudes of Knuckles Forest Reserve, Central; province, *Sri Lanka. The Sri Lanka Forester.* 26: 1-9.

Hewitt, J. 1929. On some Scincidae from South Africa, Madagascar and Ceylon. *Annals of the Transvaal Museum* 13: 1-8.

IUCN Sri Lanka. 2000. *The 1999 list of threatened fauna and flora of Sri Lanka.* Colombo: IUCN Sri Lanka. 114 pp.

Madduma Bandara, C. M. 1991. Climate and hydrology of the Dumbara Hills. *Annual Review 1990.* Institute of Fundamental Studies, Kandy. p. 51.

Rathnayake, N. D, A. N. Weerasinghe, K. Amarasinghe, C. Gamlath, D. Rathnayake, C. Irrugalrathne & H. Wijesinghe. 1999. *An ecological study on flora and fauna of Knuckles range – Sri Lanka (Northern region).* Youth Exploration Society of Sri Lanka, Peradeniya, 33 pages (mimeographed).

Smith, M. A. 1935. *The fauna of British India, including Ceylon and Burma. Reptilia & Amphibia. Vol. 11- Sauria.* Taylor & Francis, London. 440 pp.

Taylor, E. H. 1950. Ceylonese Lizards of the Family Scincidae. *University of Kansas Science Bulletin,* 33 (13): 481-518.

The Diversity of the Dumbara Mountains (The Knuckles Massif, Sri Lanka): With special reference to its herpetofauna.
Lyriocephalus Special issue, 2005 November, Volume 6 Numbers 1 & 2: 125-133
ISSN 1391-0833

SOME OBSERVATIONS ON THE GECKOS INHABITING THE KNUCKLES MASSIF

Anslem de Silva[1], Aaron M. Bauer[2], Suraj Goonewardene[3], John Drake[3], S. Nathaniel[4] & Panduka de Silva[1]

[1]*15/1 Dolosbage road, Gampola, Sri Lanka. Email: kalds@sltnet.lk*
[2]*Department of Biology, Villanova University, 800 Lancaster Avenue, Villanova, Pennsylvania 19085, USA. Email: aaron.bauer@villanova.edu*
[3]*97, Battersea Park Road, London, SW9 4DU, UK. E-mail: hsr.wild@gmail.com (University of Edinburgh, UK)*
[3]*Creagard, Isle of Mull, PA75 6RA, UK. E-mail: jfdrake@gmail.com (University of Edinburgh, UK)*
[4]*Dept of Biological Sciences, Rajarata University of Sri Lanka*

Keywords: *Cnemaspis, Geckoella triedra, Hemidactylus depressus,* Knuckles, threats.

Introduction

At the present time 25 described species and subspecies of gecko are known from the Sri Lanka. Fifteen of these are endemic (Batuwita & Bahir 2005; Deraniyagala 1953; de Silva 2001; Kluge 2001; Manamendra-Arachchi 1997; Smith 1935 and Taylor 1953). In addition to these, several new taxa of geckos have been discovered in recent times and await formal description. Thus, Sri Lanka has a high diversity of geckos, the majority of which are endemic.

The Knuckles Massif exhibits extensive variation in geology, altitude, vegetation, and climate. It thus offers ecological opportunities for many species of geckos, including the common and dominant *Cyrtodactylus soba*, a regional endemic found only in the Knuckles.

The present paper provides a provisional checklist of geckos observed at the Knuckles Massif, together with some pertinent ecological notes. The current status of, and threats to, these geckos are also briefly discussed.

Knuckles Massif: The Study Area

The vegetation, climate, relief and other physical features of this Cloud Forest are discussed in several papers in the present volume (Ratnayake 2005; Giragama & Wickramaratne 2005 and Wickramaratne & Giragama, 2005).

Methodology

The main field techniques and methods employed during this study were patch sampling, visual encounter survey, canopy investigations and quadrat sampling. In addition investigations were conducted inside houses during both the night and the day. For most geckos observed or collected the following data were recorded in a structured questionnaire: date, time, GPS location, locality, habitat, microhabitat, species, gender, measurements and obvious external damage or abnormalities. Laminated field keys were used, including the six figures giving the external features of *Cyrtodactylus* spp. as per Batuwita & Bahir (2005). Fæcal samples were collected from geckos from each new locality in a bottle containing 10% formaldehyde. The stool samples were taken to the research laboratory of Department of Veterinary Pathobiology, Faculty of Veterinary Medicine & Animal Science, University of Peradeniya, for investigation. All animals, except some taxonomically problematic forms were released back at their points of capture after being photographed. Voucher specimens (male and female, usually a single specimen of each) were collected for ongoing taxonomic investigations (with approval from the Dept. of Wildlife Conservation (DWLC) and Forest Department).

Results

In the large-scale (20 x 20 m) quadrat sampling undertaken for the project during 2004 (see de Silva *et al.*, 2005a in this volume). Only those 20 plots in which geckos were actually observed are listed in table 1. The totality of gecko species observed using all the methods and techniques mentioned above (i.e., including visual encounter, patch and canopy sampling) are included in the checklist together with some relevant ecological and field notes. It is evident that visual encounter and patch sampling were the more fruitful exercises in detecting geckos. The reason for the relatively lower success of the widely used quadrat sampling technique here is its focus on the reptile and amphibian species that inhabit leaf-litter. Many of the geckos of Knuckles do not typically occur in leaf-litter.

Table 1
Gecko Species Observed in the Large Leaf Litter Quadrats.
Project Knuckles: 2004

Plot No	Date	Habitat	Altitude (meters)	*Cyrtodactylus soba*	*Geckoella Triedra*	*Cnemaspis* Species
3	16-7	Pine plantation	1227	Nil	Nil	1 NS
4	16-7	Pine plantation	1134	Nil	1NS	Nil
5	16-7	Pine plantation	984	Nil	Nil	Eggs
6	18-7	Monsoon forest		Nil	Nil	Eggs
7	22-7	Monsoon forest		Nil	Nil	1f
9	23-7	Pine plantation	1201	Nil	Nil	1
10	23-7	Pine plantation	1155	1m	1m, 1NS	1 + eggs
13	25-7	Cardamom plantation	1250	1m	Nil	Nil
14	25-7	Cardamom plantation	1300	Nil	1m, 1NS	1
16	26-7	Cardamom plantation		Nil	Nil	1
18	2-9	Cardamom plantation	933	Nil	Nil	1
24	6-8	Acacia plantation	1095	Nil	1m, 1f	Nil
25	6-8	Acacia plantation	1095	Nil	1f, 1NS	Nil
26	6-8	Acacia plantation	1122	Nil	Nil	2 NS
27	6-8	Acacia plantation		Nil	3	1 NS
29	6-8	Fragmented forest	981	Nil	1	Nil
30	7-8	Riverine forest	1065	Nil	1	Nil
32	7-8	Riverine forest		Nil	Nil	1 NS
34	8-8	Riverine forest		Nil	Nil	2 NS
35	8-8	Riverine forest		Nil	Nil	1 NS

m = male, f = female, NS = Not Sexed

Checklist of the Geckos Observed at Knuckles with some Ecological Notes

The list below is provisional, as the validity of some species allocations needs to be confirmed with more samples and molecular studies. The genera and species are listed alphabetically. Sources consulted in preparing this list are Batuwita & Bahir, 2005; Das & de Silva, 2005; Deraniyagala, 1953; de Silva, 2001; Kluge, 2001; Manamendra-Arachchi, 1997; and Taylor, 1953. The status with respect to endemism is presented based on current knowledge. Specimens that could not be identified are also included.

Genus: *Cnemaspis* Strauch, 1887.

1. ***Cnemaspis jerdonii scalpensis*** (Ferguson, 1877). English: Jerdon's day gecko, Sinhala: Jerdonge divasarihuna. Status: Endemic.

Notes: This species referred as *Cnemaspis scalpensis* (Das & de Silva, 2005), *Cnemaspis jerdonii scalpensis* (Deraniyagala, 1953; de Silva 2001; Wickramasinghe & Somaweera, 2002) (Plate 8. Figure 1) and listed as

Cnemaspis jerdonii by Kluge (2001) is presently being investigated using molecular as well as morphological approaches (A. Bauer & A. de Silva). For the purposes of this paper it is listed as *Cnemaspis jerdonii scalpensis*. It was common on large rock outcrops as well as abandoned buildings around 800 to 1000 m above sea level at Knuckles.

At some localities, we observed colonies of up to 9 (in Pitawala Pathana) individual in one place. *C. jerdonii scalpensis* is a large species when compared to *C. podihuna*. The average SVL was 40 mm (Table 2). two gravid females observed in September, had trombiculid mites on its body. 24 specimens observed in Abandoned Human Habitations, Lower Montane Forest, Lower Montane Rock Outcrop Forest, Tropical Mixed Evergreen Forest and Upper Montane Forest, in Bambugala (824m), Dumbanagala (1132m), Emmaduwa (567m), Gammaduwa (1002m), Illukumbura (638m), Kobonilagala (1325m), Lakegala (553m), Pitawala (1162m) under corrugated iron sheets, Inside logs, leaf litter, abandoned walls, tree bases, under bark, under logs and under rocks. Total length range 70-85mm and weight range was 1.0-2.0g (n=6). Air temp range 21.8- 26.3 substrate temp 21.0- 25.9 and RH range was 43-67%.

Table 2
Some measurements of *Cnemaspis jerdonii scalpensis*
(Knuckles expedition – 2004 and 2005)

Gender	SV (mm)	Tail (mm)	Weight (gm)	Remarks
Male	40	45	2	-
Male	36	39	2	-
Male	35	38	1	-
Female	40	34	1.5	Gravid
Average	38	39	2	-

2. *Cnemaspis kandiana* (Kelaart, 1853 "1852"). English: Kandyan day gecko, Sinhala: Kandukara divasarihuna. Status: Endemic.

Notes: This species is widely distributed in the Knuckles. 30 specimens were found in Acacia Plantation, Lower Montane Forest, Pine Plantation, Riverine Forest and Tropical Mixed Evergreen Forest habitats at Deanston I1122m), Dehigolla (1155m), Dumbanagala (1049m), Elkaduwa (748m), Gammaduwa (1002), Illukumbura (476m), Kandegama (750m), Lakegala (434m), Medamahanuwara (1033m), Navanagala (1200m), Puwakpitiya (519m), Rajagala (1082m) and were found inside logs, wall, leaf litter, rock crevice, tree bases and under rocks. One gravid female was observed during the study period, which was 65mm total length.

3. *Cnemaspis podihuna* Deraniyagala, 1944. English: Dwarf day gecko, Sinhala: Kuda divasarihuna, Podi galhuna. Status: Endemic.

Notes: *Cnemaspis podihuna* (Plate 8. Figure 2) is a rarely encountered species at Knuckles. During the survey, we observed it at Yahangala (313m). It was observed on the trunk (GBH 200cm) of a forest tree 5 m above the ground in a Tropical Mixed Evergreen Forest.

4. *Cnemaspis tropidogaster* (Boulenger, 1885). English: Roughbelly day gecko, Sinhala: Ralodara divasarihuna. Status: Not endemic.

Notes: 27 specimens of *Cnemaspis tropidogaster* were observed in Pine Plantation, Riverine Forest, Tropical Evergreen Mixed Forest habitats at Allugalena (1000m), Corbett's Gap (1313m), Dawattagalla (1344m) Deanston (1130m), Elkaduwa (1225m), Hunnasgiriya (931m), Lakegala (553m), Medamahanuwara (1033m), Meemure (600m), Pitawala (926m) and Yahangala (300m). Observed inside logs,

inside rock crevice, walls of abandoned buildings, root system, tree bases and under rocks.

5. *Cnemaspis* species

Notes: A *Cnemaspis* specimen with an enlarged central subcaudal row (Plate 8. Figure 3) was discovered which could not be identified using the available keys. At the present time molecular and alpha taxonomy is underway to ascertain if this could be a new species. 3 specimans were observed in Lower Montane Rock Outcrop Forest at Bambugala (824m), on rock faces and under rocks. Total length range 72-79mm and weight was 1.5g (n=3). Two specimens were gravid females.

Notes:

Some species-specific habitat information was observed in *Cnemaspis*.

a) *Cnemaspis podihuna* was only observed on the large trunks of tall trees, (from the base to the canopy) in monsoon forests in North East Knuckles (Plate 8. Figure. 4). They were usually first detected 3 to 5 meters above the ground. When approached they were quick to run up the trunk. Two eggs are laid inside tree crevices or underneath the bark or crevices on the trunk (Plate 8. Figure 5). Though we observed several specimens of other species from various habitats in the Knuckles, we located *Cnemaspis podihuna* only a few times, suggesting its rarity.

b) *Cnemaspis kandiana* and *Cnemaspis tropidogaster* were common in rocky substrates, boulders along streams and trunks of trees in the forest, among small rocks and leaf litter on the ground and occasionally entering man-made structures, such as thatched huts, cow-sheds and houses.

c) *Cnemaspis jerdonii* was observed inside abandoned buildings and on large rock outcrops. Several large colonies comprising 10 to 15 specimens occupied the same rock outcrop. Occasionally this species enters man-made structures, such as thatched huts, cow-sheds and houses.

General Notes on Reproductive Habits of *Cnemaspis*

As regards reproductive habits, over 100 gravid female *Cnemaspis* were recorded during the Knuckles Expeditions of 2004 and 2005, as well as in the ongoing island-wide gecko survey. All these females contained two eggs each. Communal as well as individual egg laying patterns were observed:

a) Large clusters of 50 to over 100 eggs were observed, usually on a rock surface and mostly in rock caves (Plate 8. Figure 6). Some of these were the largest *Cnemaspis* egg clusters we have observed in the country.

b) Smaller clusters with 10 – 25 eggs; on rock surface inside caves and under rock flakes which were well protected from rain and sun.

c) *Cnemaspis* eggs as individual pairs attached to rock surface, tree trunks, inside crevices in house walls, terracing, leaf litter, under rock flakes, and inside rock caves were also observed.

Parasites

Internal parasites (coccidian oocysts) were observed in some *Cnemaspis* (refer de Silva *et al*, 2005 b in this issue).

Genus: *Cyrtodactylus*. Gray, 1827.

6. *Cyrtodactylus soba* (Batuwita & Bahir, 2005). English: Great forest gecko, Sinhala: Maha halae huna or Mukalam huna. Status: Endemic.

Notes:

Over 100 *Cyrtodactylus soba* were observed. Of these morphometric data and other details of habitat, gender, damage, external parasites (trombiculid mites) were recorded in a structured questionnaire. *Cyrtodactylus soba* was observed from over virtually the entire Knuckles Conservation Forest area, as well as outside the conservation area. At each new locality, one or two specimens were checked using the six external features as given by Batuwita & Bahir (2005). We found *C. soba* to be the dominant gecko species at Knuckles. It was observed on several occasions to be

sympatric with *Cnemaspis* species, *Hemidactylus depressus* and *Geckoella triedra*. A detailed account of *C. soba* is given in the present volume (de Silva *et al*, 2005c).

Genus: *Geckoella* Gray 1867.

7. *Geckoella triedra* (Günther, 1864). English: Spotted bow finger gecko, Sinhala: Pulli vakaniyahuna. Status: Endemic.

Notes: *Geckoella triedra* (Plate 8. Figure 7) was the only largely terrestrial gecko we observed at Knuckles. It is a slow moving, nocturnal gecko of medium size. Ninety five specimens were observed during the survey. Of these, details of 48 specimens were recorded in the structured questionnaire. There were 26 females, 20 males, 33 unsexed adults, and 17 juveniles/hatchlings. The total length range of adults was 70-116mm and weight was 2.0- 9.0g (n=21). Total length range of juveniles/hatchlings 45-61mm and weight was 0.5- 2.0g (n=12). During the day, it rests underneath stones, decaying logs, inside decaying logs, under rock and woodpiles and on a few occasions in leaf litter on the forest floor. They were also occasionally recorded in man-made structures, such as thatched huts, cowsheds and houses, where they were found underneath furniture. Some areas had high densities of *Geckoella triedra*.

Thirteen gravid females were observed during the expedition period (June to September). All the gravid females we examined contained two eggs. A few hatchlings measuring 25 mm SVL and tail 20 mm with visible umbilical opening were also observed. Two morphological variants of this species were found at Knuckles and molecular and alpha taxonomy is in progress. A detailed account of *Geckoella triedra* is in preparation (de Silva *et al.*, 2006 accepted for publication).

Genus: *Gehyra* Gray, 1834.

8. *Gehyra mutilata* (Wiegmann, 1834). English: Four-claw gecko, Sinhala: Caturanguli huna. Status: Not endemic.

Notes:

This is a common house gecko in other parts of the country, but at Knuckles only a few were observed in lowland human habitations at Illukumbura, Laggala Pallegama.

Genus: *Hemidactylus* Cuvier, 1820.

9. *Hemidactylus brookii parvimaculatus* Deraniyagala, 1953. English: Spotted housegecko, Sinhala: Pulli gehuna. Status: Endemic.

Notes: This is a common house gecko widely distributed in other parts of the country. However, at Knuckles only a few were observed in lowland human habitations at Illukumbura, Laggala Pallegama. The status of this subspecies relative to typical *H. brookii brookii* of India and other parts of Asia is currently under investigation.

10. *Hemidactylus depressus* Gray, 1842. English: Kandyan gecko, Sinhala: Hali gehuna. Status: Endemic.

Notes: Twenty three specimens of *Hemidactylus depressus* was observed in human habitation, Kandyan home gardens, Lower Montane Forest, Riverine Forest and Tropical Evergreen Mixed Forest at Corbet's Gap (688m), Illukumbura (476m), Kobonilla (1191m), Lakegala (705m), Nugagolla (113m), Pitawala (579m), Puwakpitiya (622m) and Rambukoluwa (242m). They were mainly found in rock crevices, cracks and depressions on rock surface and in rock caves. They were also found inside tree crevices, underneath dray bark and inside human dwellings. Whilst primarily nocturnal, a few specimens were observed to be active during the day. The morphometric data were recorded only for 10 specimens of which five were females (two gravid). The average SV = 65 mm and tail = 63 mm (number 5). Trombiculid mites were observed on some specimens. This is a widespread species in Sri Lanka and is presently undergoing molecular and taxonomic study to test our hypothesis that this may actually be more than one species.

An egg (11 mm length) was collected in August, it hatched on 28th September, 2004 in the morning. The opening was approximately 9 x 9 mm. The hatchling measured SV = 26 mm and tail = 28 mm.

11. *Hemidactylus frenatus* Schlegel, 1836. English: Common house-gecko, Sinhala: Sulaba gehuna. Status: Not Endemic.

Notes:
This is a common house gecko, widely distributed across Sri Lanka. At Knuckles only a few were observed in lowland human habitations at Illukumbura, Laggala Pallegama.

12. *Hemidactylus leschenaultii* Duméril & Bibron, 1836. English: Bark or Sycamore gecko, Sinhala: Kimbul huna = crocodile gecko, Gas huna = tree or Kumbuk huna = *Terminalia arjuna*. Status: Not Endemic.

Notes:
This is a common house gecko widely distributed in the dry zone lowlands of the country. At Knuckles only a small number were observed in the lowlands of North east Knuckles close to human habitations. This is a large, smooth-skinned gecko, Primarily nocturnal but can also be active during the day.

13. *Hemidactylus triedrus lankae* Deraniyagala, 1953. English: Termite hill gecko, Sinhala: Humbas huna. Status: Endemic.

Notes:
This beautiful ground gecko is spotted and has dark and light bands (Plate 8. Figure 8). A common gecko is widely distributed in the dry zone lowlands of the country. At Knuckles only a few were observed in the lowlands of North-east Knuckles, around Laggala Pallegama, north of Lakegala and at Ilukkumbura. They were observed on termite mounds at night.

Table 3
Current Status of Geckos Inhabiting Knuckles and Sri Lanka
(Data from present study)

Genera	No in Sri Lanka	No Endemic to Sri Lanka	No. in Knuckles
Calodactylodes	1	1 (100%)	Nil
Cnemaspis	4	3 (75%)	4
Cosymbotus	1	Nil	Nil
Cyrtodactylus	6	6 (100%)	1
Geckoella	3	2 (66%)	1
Gehyra	1	Nil	1
Hemidactylus	7	3 (43%)	5
Hemiphyllodactylus	1	Nil	Nil
Lepidodactylus	1	Nil	Nil
Total	25	15	12

Threats Faced by the Geckos at Knuckles
An area of 17.500 ha of the Knuckles range of mountains above 1,067 m was declared a conservation forest in May 2000. However, the geckos at Knuckles face many threats. The greatest of these are deforestation, fragmentation and alteration of natural habitats, the building of new houses and hotels and the attendant disturbance brought by man and his domestic animals.

a) Predators
There are many buildings within the protected area as well as immediately below the conservation boundary. In fact, during the survey period July to September 2005, several houses, guest houses and additional new buildings were being constructed. During the survey, we observed that many householders had 10 to 15 poultry and a few domestic cats. These domestic cats and poultry are known predators of agamids, geckos, skinks and snakes. They thus pose an important new threat to the reptiles of the Knuckles (de Silva, 2001, de Silva *et al.*, 2004).

At Knuckles, the domestic poultry are let loose to feed. We observed that while prowling leaf litter, the chickens came across several skinks and hatchling snakes which were pecked and eaten. The poultry also feed on large quantities of various insects – which constitute the mainstay of lizard diets. Domestic cats were also observed to feed on geckos, agamids and birds.

At Mimura, Knuckles we undertook a survey of 27 adults and students asking them to state which animals they had seen preying on geckos. The domestic cat was shown to be the main predator – witnessed by 96% of those surveyed. This was followed by snakes (48%) and ants (41%) (de Silva *et al*, 2005u Table 3).

Table 3
Gecko Predators Observed at Mimure, Knuckles: 2004

Gecko Predator	No. of Students	No. of Adults	Total (percent) Witnessing Gecko Predation
Frogs	-	-	-
Snakes	9	4	13 (48%)
Monitor lizard	-	1	1 (4%)
Agamid lizards	1	2	3 (11%)
Birds	2	3	5 (19%)
Cats	21	5	26 (96%)
Dogs	-	-	-
Ants	10	1	11 (41%)

Source: de Silva *et al*, 2005d

b) Forest Fires

Over 1000 hectares of forests and grasslands are set on fire annually at Knuckles (Plate 9. Figure 7). These fires may be a serious threat to the herpetofauna, including eggs that are laid in leaf litter. Some skinks, agamids, snakes, geckos and direct developing frogs may all lay their eggs under leaf-litter and humus. Thus numerous species can be adversely impacted. During investigations carried out at Knuckles immediately after burning we came across burnt *Cyrtodactylus soba* (Plate 9. Figures 8). Although we did not observe burnt specimens of the terrestrial *Geckoella triedra*, with it being a more ground dwelling species than *C. soba* it is quite possible that it may also suffer. Grievous injuries and severe burns to *Geochelone elegans*, the star tortoise have been observed when agricultural fields are set on fire (de Silva, 2003).

c) Agrochemical use

Pesticides were first used in Sri Lanka to control malaria in 1946. Since then there has been a gradual increase in their use.
Presently some 100 active agents are applied to the environment for either agricultural or public health purposes. During the survey we observed the application of insecticides at several locations close to the conservation area border. This is highly likely to be disruptive to the local ecosystem and potentially impact the geckos adversely.

Conservation, Awareness and the Management of Geckos at Knuckles

The two relevant authorities, the Department of Wildlife Conservation and the Forests Departments should, with the help of relevant parties, conduct an preliminary survey to assess the threats faced by geckos at every stage of their life cycle at Knuckles. The buffer zone around the conservation area needs reassessment. The keeping of cats and poultry should be allowed only outside of this buffer zone.

As an awareness program all houses we visited at the Knuckles were issued with two special stickers informing residents of the useful nature of the geckos (Plate 5 Figures 5 & 6).

Acknowledgements

We wish to thank: Mr. Sarath Fernando, Director General, Forest Department for permission granted to (AdS, AB and CA) (FRC/5 and FRC/6) to conduct the above study. Director General, Department of Wildlife Conservation, Mr. H. D. Rathnayake for approvals (WL/3/2/1/14/12). The Forest Department officers at Loolwatte and Illukumbura for their friendly support throughout the study. Manel Goonasekera, Head Department of Biological Sciences, Rajarata University of Sri Lanka for her support from the inception of the project. University of Edinburgh, UK for the approval given (to University of Edinburgh students) and the generous grant. Royal Geographical Society of UK for the grant. A special thanks to Laura Packham, Polly Bramham, Alasdair Ford, Douglas Fraser and A. J. G. Burns for their help in the field to collect data.

Aaron Bauer was supported by Villanova University and by Grant DEB 0515909 from the National Science Foundation. Global Gecko Association (John Rudge) for sponsoring the gecko stickers. John Rudge made useful comments in draft stages.

Literature cited

Batuwita, S. & M. M. Bahir. 2005. Description of five new species of *Cyrtodactylus* (Reptilia: Gekkonidae) from Sri Lanka. In: Yeo, D. C. J., P. K. L. Ng & R. Pethiyagoda (eds.), Contributions to biodiversity exploration and research in Sri Lanka. *The Raffles Bulletin of Zoology*, Supplement No. 12: 351–380.

Das, I. & Anslem de Silva. 2005. *A photographic guide to snakes and other reptiles of Sri Lanka.* New Holland, UK., 144 pp.

de Silva, Anslem. 2001. *The Herpetofauna of Sri Lanka: historical aspects and current status.* Ministry of Environment, 100 pp + 150 plates .ISBN 955-96005-0-8.

de Silva, Anslem. 2003. *The Biology and status of the star tortoise (Geochelone elegans) in Sri Lanka.* Ministry of Environment, 100 pp + 16 plates.

de Silva, Anslem., A. Bauer, C. C. Austin, S. Goonewardene, Z. Hawke, V. Vanneck, A. Drion, P. De Silva, B. J. K. Perera, R. L. Jayaratne & M. M. Goonasekera. 2004. Distribution and the natural history of *Calodactylodes illingworthorum* (Reptilia: Gekkonidae) in Sri Lanka: preliminary findings. *Lyriocephalus* Special Issue, Vol. 5, Nos. 1 & 2: 192 - 198.

de Silva, Anslem, S. Goonewardene, J. Drake, P. de Silva, R. D. C. S. K. Dasanayaka, A. M. R. K. Amarakoon, & M. M. Goonasekera. 2005a. Species diversity and richness of the herpetofauna in large leaf litter plots in the Knuckles ecosystem. *Lyriocephalus* Special issue, Volume 6 Numbers 1 & 2.

de Silva, Anslem, R. P. V. J. Rajapaksa, R.R.M.K.K. Wijesundera, M. de Silva, A. Bauer, S.Goonewardene, J. Drake, C.C. Austin, N. A. N. D. Perera, D. de Silva, & U. Hemachandra. 2005b. Preliminary observations on some parasites of geckos, skinks and snakes inhabiting the Knuckles massif. *Lyriocephalus* Special issue, Volume 6 Numbers 1 & 2.

de Silva, Anslem, A. Bauer, S. Goonewardene & J. Drake. 2005c. The Dumbara bent toed gecko (*Cyrtodactylus soba*): the dominant Gekkonid lizard inhabiting the Knuckles massif. *Lyriocephalus* Special issue, Volume 6 Numbers 1 & 2.

de Silva, Anslem, A. Bauer, S. Goonewardene, J. Drake, G. S. Samarawickrama & M. M. Goonasekera. 2005d. Some cultural traits and attitudes of the inhabitants of Mimure (in the Knuckles massif) towards local animals, with special reference to the herpetofauna. *Lyriocephalus* Special issue, Volume 6 Numbers 1 & 2.

de Silva, Anslem., S. Goonewardene, J. Drake, P. de Silva. 2006. Some observations on *Geckoella triedra* (Günther, 1864) inhabiting the knuckles massif, Sri Lanka. *Gekko.* Journal of the Global Gecko Association. (in preparation)

Deraniyagala, P. E. P. 1953. *A Colored atlas of some vertebrates from Ceylon, Vol.2, Tetrapod reptilia.* Ceylon National Museum, 101 pp.

Giragama, W.M.G.B. & S.N. Wickramaratne. 2005. Climate and cloud study in the Knuckles massif. *The Diversity of Dumbara Mountains (Knuckles Massif, Sri Lanka): With special reference to its herpetofauna. Lyriocephalus* Special issue, 2005, Volume 6 Numbers 1 & 2.

Kluge, A. G. 2001. Gekkotan lizard taxonomy. *Hamadryad*, 26(1): 1-209.

Manamendra – Arachchi, K. 1997. Gecko! *Sri Lanka Nature*. 1(1): 45-55.

Ratnayake, H. D. 2005. Some aspects of the vegetation of the Knuckles ecosystem. *The Diversity of Dumbara Mountains (Knuckles Massif, Sri Lanka): With special reference to its herpetofauna. Lyriocephalus* Special issue, 2005, Volume 6 Numbers 1 & 2.

Smith, M. A. 1935. *The fauna of British India, including Ceylon and Burma. Reptilia & Amphibia. Vol. 11- Sauria*. Taylor & Francis, London. 440 pp.

Taylor, E. H. 1953. A Review of the Lizards of Ceylon. *University of Kansas Science Bulletin*. 35 (12): 1525-1585.

Wickramaratne, S. N. & W.M.G.B. Giragama. 2005. Some geological aspects of the Knuckles massif. *The Diversity of Dumbara Mountains (Knuckles Massif, Sri Lanka): With special reference to its herpetofauna. Lyriocephalus* Special issue, 2005, Volume 6 Numbers 1 & 2.

Wickramasinghe, M. & R. Somaweera 2002. Distribution and current status of the endemic geckos of Sri Lanka. *Gecko* 3(1): 2-13.

Plate 8

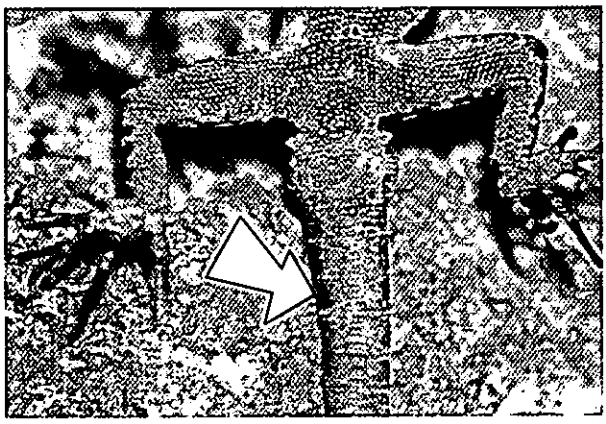


Figure 1. *Cnemaspis jerdonii*

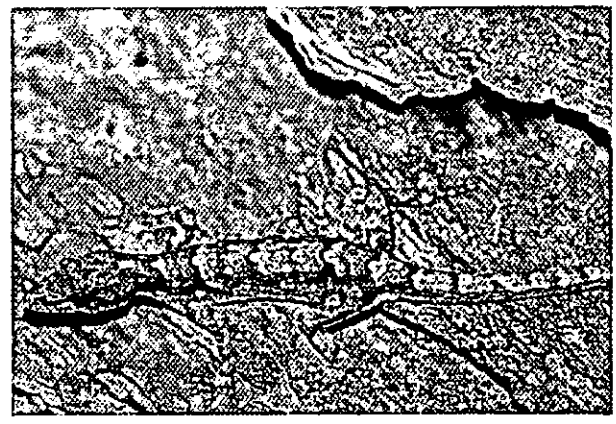


Figure 2. *Cnemaspis podihuna*

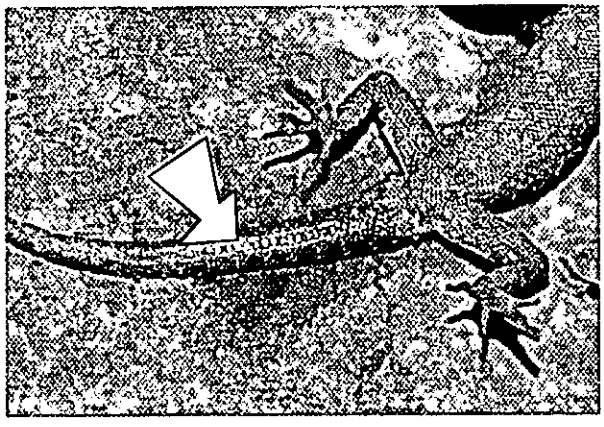


Figure 3. Unidentified *Cnemaspis*

Figure 4. *C. podihuna* habitat

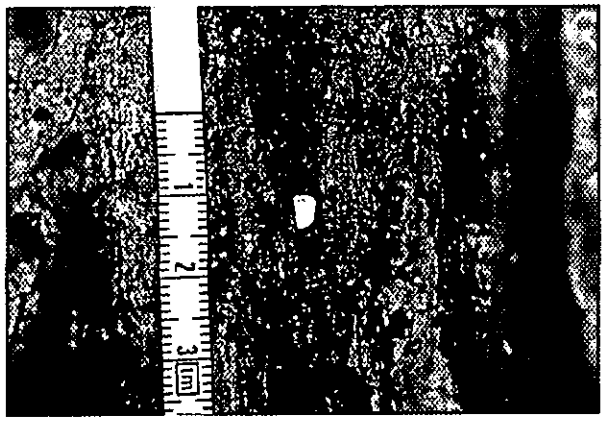


Figure 5. *C. podihuna* eggs

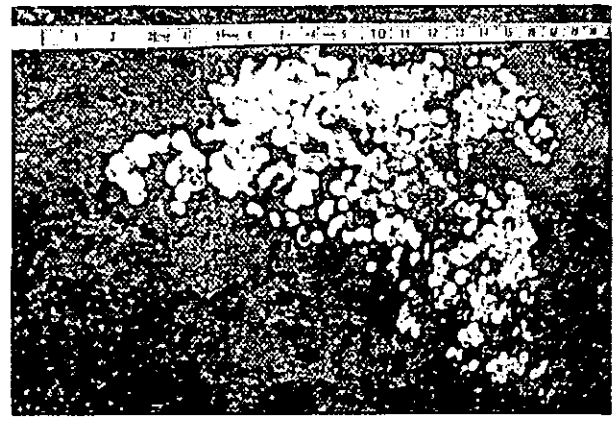


Figure 6. *Cnemaspis* egg cluster

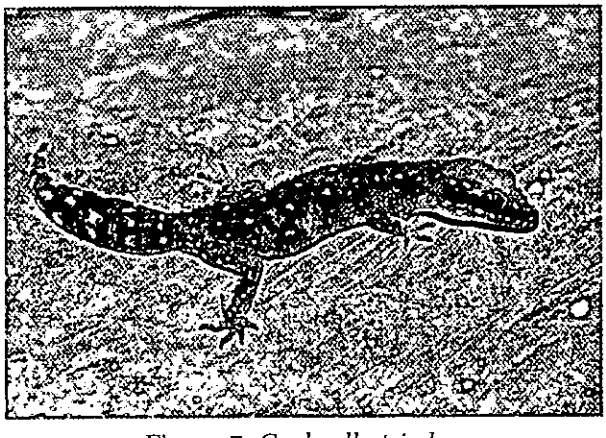


Figure 7. *Geckoella triedrus*

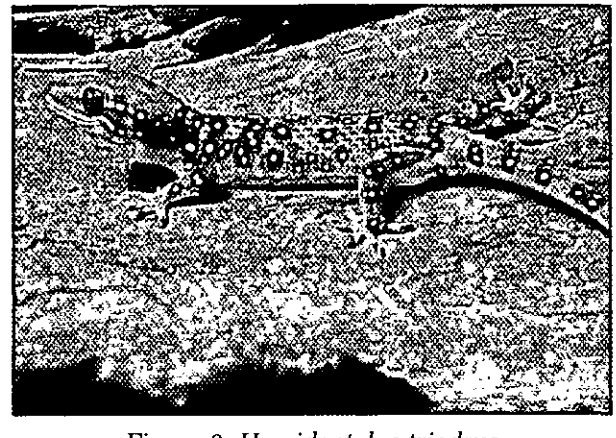


Figure 8. *Hemidactylus triedrus*

Photographs: © Suraj Goonewardene and Anslem de Silva

The Diversity of the Dumbara Mountains (The Knuckles Massif, Sri Lanka): With special reference to its herpetofauna.
Lyriocephalus Special issue, 2005 November, Volume 6 Numbers 1 & 2: 137-144
ISSN 1391–0833

THE DUMBARA BENT TOED GECKO (*CYRTODACTYLUS SOBA*): THE DOMINANT GEKKONID LIZARD INHABITING THE KNUCKLES MASSIF

Anslem de Silva[1], Aaron Bauer[2], Suraj Goonewardene[3], John Drake[3] & Panduka de Silva[1]

[1]15/1 Dolosbage Road, Gampola, Sri Lanka. Email: kalds@sltnet.lk
[2]Department of Biology, Villanova University, 800 Lancaster Avenue, Villanova, Pennsylvania 19085, USA. Email: aaron.bauer@villanova.edu
[3]97, Battersea Park Road, London, SW9 4DU, UK. E-mail: hsr.wild@gmail.com (University of Edinburgh, UK)
[3]Creagard, Isle of Mull, PA75 6RA, UK. E-mail: jfdrake@gmail.com (University of Edinburgh, UK)

Keywords: *Cyrtodactylus soba*, distribution, reproductive habits, threats, conservation, Knuckles.

Introduction

The three largest species of gekkotan lizards in Sri Lanka, *Hemidactylus maculatus hunae* Deraniyagala, 1937, *Calodactylodes illingworthorum* Deraniyagala, 1953 and *Cyrtodactylus soba* Batuwita and Bahir, 2005 each reach a maximum total length of 30 cm. The first two species are found in the lowlands of the dry and intermediate climatic zones up to about 500 m above sea level in Monaragala, Ampara and Hambantota Districts. *C. soba* is mainly confined to the Knuckles Massif, where it is common and is the dominant gecko species. *C. soba* is also known to lay the largest eggs of any gecko in Sri Lanka. However, its ecology is poorly known except for brief notes by Deraniyagala (1932, 1953) and Henry (1928). Here we report for the first time findings on the ecology of this endemic gecko.

Nomenclatural note

This gecko was until very recently considered to be the same species as another Sri Lankan gecko – *C. fraenatus* (Günther, 1864) (see Deraniyagala 1953; Kluge, 1993; Smith 1935; de Silva 1994, 1995, 2001; Manamendra-Arachchi, 1997). However, in a recent study of the genus *Cyrtodactylus* Gray, 1827 by Batuwita and Bahir (2005), five new species have been described from Sri Lanka. This study also confirmed that the well known *C. fraenatus* (Günther, 1864), is restricted to Kandy and its environs. The similar *C. soba* is largely confined to the Knuckles Massif. *C. soba* has been given the common name of the Dumbara Bent-toed gecko (Dumbara is the ancient Sinhala name for the Knuckles Massif). Its Sinhala name is *Dumbara vakniyai huna.*

Morphology, colouration and morphometry

Cyrtodactylus soba is a large gecko (Plate 9 Figures 1 & 2). Male body mass (*mean* = 19.6g, *SD* = 5.25) is greater than the mean body mass of the females in the sample shown when including both the gravid and non-gravid specimens together (*mean* = 17.0g, *SD* = 7.9). However, the difference was not significant (two sample *t*-test, $t=0.64$, $p = 0.53$, $d.f. = 12$). Gravid females, although heavier (*mean* = 20.7g, *SD* = 10.3, $n = 3$) did not have significantly greater mass than non-gravid females (*mean* = 15.2g, *SD* = 6.4, $n = 6$; $t = 0.97$, $p = 0.36$, $d.f. = 7$). Snout to vent length was also greater in males (mean = 93.1, *SD* = 19.1, $n = 8$) than in females (*mean* = 85.9, *SD* = 20.2, $n = 19$) but again the difference was not significant ($t = 0.88$, $p = 0.39$, $d.f. = 13$). The snout to vent

length of day old hatchlings measured 38 to 41 mm and tail 40 mm.

In *C. soba* the head is not depressed; the snout is short, the body robust. There are 6–7 lamellae beneath the fourth toe. Claws are short; mental subpentagonal; 61–72 dorsal scales across the midbody between ventrolateral folds; 25–31 tubercles on paravertebral row; 7–10 longitudinal rows of middorsal tubercles; ventral scales imbricate, with pointed posterior edges; tail is long, slender and subcylindrical. The dorsum is grey-brown, with five dark brown bands, a canthal stripe of the same colour meets at the nape; the flanks have a marbled pattern; the forehead has dark spots. The distal end of the tail of hatchlings and juveniles is white (Plate 9. Figure 3).

It is not easy to tell *C. soba* and *C. fraenatus* apart given their similarity in size and colouration. However, whereas in the former the dorsal scale count across the midbody is 61-72, in the latter the corresponding count is 35.

Table 1
Measurements of few *Cyrtodactylus soba* observed:
Project Knuckles 2004
(Length in millimeters and body mass in grams)

Sex	SVL (mm)	Tail length (mm)	TL (mm)	Mass (g)
Male	107	112	219	18.5
Male	104	112 (regenerated)	216	28.4
Male	102	112 (regenerated)	214	17.2
Male	91	110	201	14.5
Male	103	112 (regenerated)	215	19.4
Male Average	**101**	**111**	**213**	**19.6**
Female	68	82	150	7.4
Female	89	92	181	19.6
Female	110	170	280	24.5
Female	89	104 (regenerated)	193	10.7
Female	83	97(regenerated)	180	9.8
Female (gravid)	79	73 (regenerated)	152	8.8
Female (gravid)	110	100 (regenerated)	210	25.6
Female (gravid)	114	93 (regenerated)	207	27.6
Female Average	**93**	**101**	**194**	**16.8**

Distribution

C. soba seems to be confined to the Knuckles region. The following forest types were recognized in the Knuckles region by Rosayro (1958), Balasubramaniam (1988) and Werner (1982):

(1) Lowland wet semi-evergreen forests,
(2) Mid-elevational wet semi-evergreen forests,
(3) Mid-elevational dry-evergreen forests and
(4) Montane wet-elevational forests (Cloud forest).

C. soba was observed in all of these forest types within the Knuckles range. The species was also observed to be common in the mid-elevational dry-evergreen forests around Lakegala. *C. soba* was observed at: Allugalena (1000m), Corbet's Gap (1313m), Deanston (816m), Dehigola (1191m), Dotalugala (1550m), Dumbanagala (1132m), Hare Park (1315m), Hunnasgiriya (1092m), Kobonilagala (1458m), Kobonilla (1191m), Lakegala (705m), Loolwatte (1013m), Medamahanuwara (1033m), Nitre cave (550m), Pitawala Pathana (852m), Rangala (1164m), Sphinx Rock (1313m) and Udadumbura(872m).

Habitat

During the day *C. soba* remains concealed underneath loose dried bark and in crevices in tree trunks. These are generally located in densely shaded areas such as rock gullies and caves in forests and plantations. However, in the Knuckles this natural environment has changed considerably over the past two centuries due to the clearing of a major portion of the virgin forests to grow coffee, tea and cardamom. New residences, factories, labour housing and barns have also altered the environment. Thus, the reduction of its natural habitat has forced *C. soba* to extend its niche to live in anthropogenic habitats. It is now common, for example, inside houses (occupied as well as abandoned), inside culverts, in cardamom barns, in tea factories and other buildings on tea plantations. Individuals in these types of habitat remain concealed during the day behind household furniture, pictures hanging on walls, in the ceiling, amongst stacked planks and inside store rooms, mainly in dark and cool places. They emerge at dusk (around 17:30 to 18:00 hours) onto walls and other open places and wait in ambush for prey. They may also initially use the walls to thermoregulate before embarking on other activities. Active control of body temperatures at night by selection of appropriate substrates by gekkonidae is known (Avery, 1982). This behaviour was observed in the residence at Kobonila occupied by researchers during Project Knuckles. Several adults and eggs were also observed inside the electrical-generator room of the same house.

There was a clear preference in habitat and microhabitat, which was significant (Pearsons correlation Table 2)

Table 2

Habitat	Total no observations	%
Abandoned & Occupied Human Habitation	57	70.4
Pine	3	3.7
Lower Montane Forest	13	16.0
Tropical Evergreen Mixed Forest	7	8.6
Upper Montane Forest	1	1.2
Total	81	

Microhabitat	Total no observations	%
Abandoned & Occupied Human Habitation walls	51	63.0
Abandoned & Occupied Human Habitation other	6	7.4
Natural habitats	24	29.6
Total	81	

Behaviour

Cyrtodactylus soba is a nocturnal and arboreal gecko. Hatchlings were observed to sleep during the day with their tails and body slightly curled. Although this is one of the largest geckos in the country and several were observed inhabiting the house occupied by the Project Knuckles researchers, they were never heard calling except 'chirrupy' communications. Individuals were observed to occupy the same place for a few days and not appear to move more than a couple of meters. Occasional caudal luring by some adults was observed. Changing body colour according to the background was evident; specimens on walls of houses with white plaster were paler, some lacking any markings, whilst specimens observed on wattle and daub walls appeared darker. *C. soba* was also observed living sympatrically with the Kandyan gecko *Hemidactylus depressus* Gray, 1842 within the researchers' lodgings. A single *H. depressus* appeared to forage at the same location and time as *C. soba*. *H. depressus* was frequently found in very close proximity to *C. soba* - at a distance of less than 300 mm on a number of nights. When the two species were in close proximity both appeared to bear similar colouration. (N.B. as the former bears some superficial resemblance to *C. soba*, on several occasions only close observation facilitated the correct identity of each species). *H. depressus* were observed to emerge later than *C. soba*. The former was quicker to run when approached. On several occasions *Cnemaspis* species was observed in sympatry with *C. soba*.

Territorial habits were observed in *C. soba*. Several specimens repeatedly occupied the same place on walls, ledges and beams between 18:00 and 20:00 hours. The hatchlings appear later at night. This could be to avoid potentially predatory adults.

When *C. soba* was captured for measuring and faecal sampling, a few autotomised their tails. Many specimens bit fingers, two everted their hemipenis and several defecated. Some when captured made a chirrupy sound. A number of observations were made from midnight to the early hours of the morning of both adults and young hanging on the edge of the eaves of a roof. The adults were seen to jump from the roof to nearby trees, which were approximately 30 – 40 cm away. This change of habitat may be due to foraging. Similar change of habitat has been observed in *Calodactylodes illingworthorum*, which jumped off the boulders they had been sitting on at around dusk (1800 hours) onto the surrounding vegetation to forage. They returned to the rock outcrops early in the morning around 0430 to 0600 hours (de Silva *et al* 2004b). A similar behaviour has been reported in the Australian gecko, *Pseudothecadactylus lindneri*, which moves from sandstone outcrops onto vegetation to feed (Bauer, 1990).

Thermoregulation

Body temperature and associated environmental temperature of 18 *C. soba* geckos was recorded. The maximum body temperature recorded was 32.7°C and the minimum 17.9°C. Means with standard deviations were; body temperature = 23.8°±3.5°, air = 23.3°±2.6°, substrate = 23.7°±4.9°. A two-sample *t*-test indicated no differences between body and substrate or air temperatures; against air temp $p = 0.63$, against substrate temp $p = 0.91$. There was also no significant departures in body temperature variance from variance in environmental temperatures; against air temperature $F = 1.81$, $p = 0.29$, against substrate temperature $F = 0.51$, $p = 0.23$. These preliminary results suggest the lizards are thermoconformers, not attempting to control body temperature.

Diet

C. soba has been observed to eat crickets. In captivity it ate cockroaches voraciously, even accepting some by hand. This could explain why it is common inside human dwellings where cockroaches abound. Henry (1928) reports one devouring a tree-frog of quite substantial size. Deraniyagala (1932, 1953) records it feeding on insects, small birds and other smaller geckos. Wickramasinghe & Somaweera (2002) report observing captive specimens feeding on chicks and pink mice.

Reproductive habits

Of the 77specimens of *C. soba* observed, 55 specimens were checked for the gender: 23 were male, 32 were female suggesting that females are the more abundant (Table 1). Four gravid females were observed in July and August 2004. Eggs were also observed during July. The average snout to vent length of a gravid female was 97 mm and the average total length (all had regenerated tails) was 191 mm. The smallest gravid female measured 79 mm (SVL) and the largest 114 mm. The gravid females contained 2 eggs each, suggesting that two eggs is the usual number laid. *C. soba* was observed to lay eggs communally.

C. soba eggs are the largest gecko eggs recorded in Sri Lanka to date. The eggs observed measured 18 x 15 mm (Plate 9. Figures 4).

C. soba appears to lay its eggs in a variety of places: crevices in stone embankments and walls (Plate 9. Figures 5), tree holes and in leaf litter. Eggs have also been dug up from a garden (Henry, 1928). The variety of egg-laying sites indicates that this species is not confined to certain types of egg-laying areas as, for example, is *Calodactylodes illingworthorum,* which deposits its eggs on the inner surfaces of rock caves and beneath rock overhangs.

The following are random observations made on *C. soba* eggs:

1. 12th July 2004: six hatched egg shells inside a crevice in a stone embankment outside an abandoned cardamom barn beside the Mimure road traversing Corbett's Gap.

2. August 2004: four eggs inside a hole about 1 m above ground in a large tree along riverine forest. The tree hole measured 50 mm x 100 mm and 180 mm deep, the inside temperature was 23.6°C and outside air temperature 25.4 °C.

3. 14 July 2004: eight eggs inside a crevice (100 x 50 and 300 mm deep) in a stone wall of an abandoned house (Plate 9. Figures 5) close to Alulengala lena cave. The temperature inside the crevice was 19.8°C and the relative humidity was 72%. The atmospheric temperature was 23.9°C and relative humidity 78%.

4. 18 July 2004: several hatched eggs and a single decayed egg at a base of a large tree among leaf litter along Nitre Cave trail.

5. July 2004: four eggs inside the generator room of Eagles Rest, Kobonila, on a ledge 600 mm above ground. The eggs were deposited on a shallow layer of sand. There appeared to be no evidence that the parent had attempted to conceal the eggs.

Two eggs from the above location were removed for ex-situ incubation and for further study of development and the hatchlings:

The measurements of the eggs were 18 x 15 mm (egg No. 1) and 17 x 15 mm (egg No.2). Egg No. 1 hatched on the evening of 13th September 2004, nearly 60 days after collection. The foetus had made an incision approximately 11 mm long. After emerging from the egg, the hatchling started to feed on the extra embryonic membranes. When observed on the morning of the 14th around 8.00 am the hatchling had wrinkled skin. However, by evening it had undergone ecdysis. It was assumed that it had eaten the skin, as there was none left inside the cage. When measured two days later, the hatchling was 38 mm from the snout to vent and its tail was 40 mm.

Egg No.2 hatched at noon on 23 September, approximately 70 days after collection. This hatchling was of a darker colour with a pinkish-white tail end. On the first day it measured 41 mm from snout to vent and its tail was 40 mm.

On 5 October the weight of hatchling (1) was 1.27 g and hatchling (2) weighed 1.18 g. The umbilical opening of hatchling (2)

was more or less fused, but a scar was visible.

A hatchling with an umbilical scar was captured on August 2nd around the chimney at Knuckles at about 00:10 hours. It weighed 1.5g and measured 40mm from snout to vent, with a tail of 42mm.

Henry (1928) reports that he received six eggs dug up from a garden at Mausakanda Estate, Gammaduwa on 13th June, 1927. He observed on June 25th that one egg had hatched. After a few hours the hatchling had moulted and eaten the moult. The hatchling measured 42.5 mm from snout to vent with a tail 47 mm (Henry, 1928). The eggs measured 18 x 15 mm. The fact that the eggs hatched in two different periods suggested two different clutches.

Parasites

Of the 81 *C. soba* specimens observed, 10 had red mites or "chiggers" (Plate 9. Figure 6). Chiggers are the larval stage of Trombiculid mites. Mite infestations such as this are common on geckos.

Status, Threats and Conservation

Earlier literature considered *C. soba* as a rare lizard (Ginige, 1995, Manamendra-Arachchi, 1997). However, during the Knuckles survey we observed a healthy population of nearly seventy odd specimens. Thus, in the Knuckles *Cyrtodactylus soba* could be regarded as the common "House gecko". The more typically common house geckos: *Hemidactylus brookii parvimaculatus, Hemidactylus frenatus* and *Gehyra mutilata* were rare. There are several hundred houses in the Knuckles of which around 20 houses were inspected during the survey - each harboured 2 to 10 specimens of *Cyrtodactylus soba* in them.

Our results suggest that there are no immediate threats to this species, given that it occurs over a large range with relatively high frequency, both in relatively undisturbed and anthropogenic habitats. Indeed, it may be said to be commensal. Whilst its frequency and distribution should be periodically monitored, we recommend that it be categorised as Least Concern.

However, we do feel the following specific matters should be investigated and action considered:

- Many of the houses within and just on the border of the Knuckles conservation area had cats and poultry. Earlier studies have shown that domestic cats are predators and major threats to geckos (de Silva, 2001; de Silva *et al*, 2004a). Furthermore, a survey on the "knowledge, attitude and practice" of some inhabitants at Mimure in Knuckles, showed that they have seen cats preying on geckos (species not defined) (de Silva et al, 2005, in this volume).
- Many parts of Knuckles are fired annually. During the survey period (June to August, 2004) we observed six outbreaks of fire in the forest and plantations within the Knuckles Conservation area (Plate 9. Figure 7). These were started by people living in the area, probably to hunt animals. However, the exact number of annual forest fires at Knuckles is unknown. We found a burnt *Cyrtodactylus soba* (Plate 9. Figure 8) after one such fire.

- Ascertain the long-term effects of red mites or "chiggers" on *Cyrtodactylus soba* so as to establish whether these parasites impact on the viability of the population of the gecko. Localized skin damage caused by such mites is known (Bauer *et al*. 1990) so the presence of chiggers needs to be investigated to assess their impact on morbidity and mortality of this gecko

Acknowledgements

We wish to thank: Mr. Sarath Fernando, Director General, Forest Department for permission granted to (AdS, AB and CA) (FRC/5 and FRC/6) to conduct the above study. Director General, Department of Wildlife Conservation for approvals (WL/3/2/1/14/12). The Forest Department officers at Loolwatte and Illukumbura for their friendly support throughout the study.

Manel Goonasekera, Head Department of Biological Sciences, Rajarata University of Sri Lanka for her support from the inception of the project.

University of Edinburgh, UK for funding and supporting Project Knuckles 2004 undergraduate research expedition (especial thanks to the following University of Edinburgh Funds: Aranmore Memorial Traveling Scholarship, Davis Fund, James Rennie Bequest, Student Travel Fund, Weir Fund, William Dickson Traveling Fund and also British Student Travel Fund, Edinburgh No. 2 Fund, Gilchrist Educational Trust, Lindeth Charitable Trust, Peoples Trust for Endangered Species, Royal Geographical Society Expedition Research Grant (Gumby Award). BP (British Petroleum) for the generous grant. Also thanks to Alasdair Ford, Andrew Burns, Douglas Fraser, Laura Packham and Polly Bramham from Project Knuckles 2004 for helping to gather data in the field. John Rudge made some useful comments and Roger Meek helped with data analysis.

Aaron Bauer was supported by funds from the Department of Biology at Villanova University. USA.

Literature Cited

Avery, R. A. 1982. Field studies of body temperatures and thermoregulation. In: Biology of the Reptilia 12, Physiology C; Physiological Ecology p. 93 – 166. Gans, C. & Pough, F.H. Eds, London: Academic Press.

Balasumbramaniam, S. 1988. The major forest formations of the Knuckles region. Preliminary workshop for the preparation of a conservation plan for the Knuckles range of forests (Mimeograph), Forest Department, Colombo, Sri Lanka.

Batuwita, S. & M. M. Bahir. 2005. Description of five new species of *Cyrtodactylus* (Reptilia: Gekkonidae) from Sri Lanka. In: Yeo, D. C. J., P. K. L. Ng & R. Pethiyagoda (eds.), Contributions to biodiversity exploration and research in Sri Lanka. *The Raffles Bulletin of Zoology*, Supplement No. 12: 351–380.

Bauer, A. M. 1990. Phylogenetic systematics and biogeography of the Carphodactylini (Reptilia: Gekkonidae). *Bonner Zoologische Monographien* 30:1-220.

Bauer, A. M., A. P. Russell & N. R. Dollahon. 1990. Skin folds in the gekkonid lizard genus *Rhacodactylus*: a natural test of the damage limitation hypothesis of mite pocket function. *Canadian Journal of Zoology* 68:1196-1201.

Deraniyagala, P. E. P. 1932. The gekkonoideae of Ceylon. *Spolia zeylanica* 16(3): 291-310. 7 plates.

Deraniyagala, P. E. P. 1937. A new gecko *Hemidactylus maculatus hunae*. Ceylon Journal of Science, 20: 185-189.

Deraniyagala, P. E. P. 1953. A coloured atlas of some vertebrates from Ceylon. Vol.2 Tetrapod Reptilia. Ceylon National Museums Publication.Ceylon Govt. Press. 101 pp.

De Rasayro, R.A. 1958. The climate and vegetation of the knuckles region of Ceylon. The Ceylon Forester, Vol.III. (3 & 4), 201-260.

De Silva, Anslem. 1994. Some notes on *Gonydactylus frenatus* (Günther, 1864) (Reptilia: Gekkonidae). *Lyriocephalus*, 1(1&2): 57-59.

De Silva, Anslem. 1995. Further notes on *Cyrtodactylus frenatus* (Reptilia: Gekkonidae). *Lyriocephalus* 2(1&2):60.

De Silva, Anslem. 2001. The Herpetofauna of Sri Lanka: historical aspects and current status. Ministry of Environment, 100 pp + 150 plates. ISBN 955-96005-0-8.

De Silva, Anslem. A. Bauer, C. C. Austin, S. Goonewardene, Z. Hawke, V. Vanneck, A. Drion, B. J. K. Perera, R. I. Jayaratne & M. M. Goonasekera. 2004a. Some cultural traits of the inhabitants of the Nilgala Fire savannah, Sri Lanka, towards animals: with special reference to the herpetofauna. *Lyriocephalus* Special Issue. 2004, Vol. 5 , Nos. 1 & 2: 183-191.

De Silva, Anslem. A. Bauer, C. C. Austin, S. Goonewardene, Z. Hawke, V. Vanneck, A. Drion, P. de Silva, B. J. K. Perera, R. I. Jayaratne & M. M. Goonasekera 2004b. Distribution and the natural history of *Calodactylodes illingworthorum* (Reptilia: Gekkonidae) in Sri

Lanka: preliminary findings. *Lyriocephalus* Special Issue. 2004, Vol. 5, Nos. 1 & 2: 192-198.

de Silva, Anslem , A. M. Bauer, S. Goonewardene, J. Drake, S. Nathaniel, M. M.

Goonasekera. 2005. Some observations on the geckos inhabiting the Knuckles Massif. *The Diversity of Dumbara Mountains (Knuckles Massif, Sri Lanka): With special reference to its herpetofauna. Lyriocephalus*, Volume 6 Numbers 1 & 2:

Ginige, P. 1995. Reptile fauna of the Knuckles Range, Sri Lanka, *Lyriocephalus*. 1(1 & 2): 38–43.

Gray, J. E. 1827. A synopsis of the genera of saurian reptiles, in which some new genera are indicated, and the others reviewed by actual examination. Philosophical Magazine, 2: 54–58.

Gray, J. E. 1842. Description of some new species of reptiles, chiefly from the British Museum collection. *The Zoological Miscellany*, 1842: 57–59.

Günther, A. L. C. G. 1864. Reptiles of British India. Ray Society, London. 452 pp.

Henry, G. M. 1928. Notes on the Gecko, *Gymnodaetylus frenatus. Spolia Zeylanica*. 14(2): 339-340.

Kluge, A. G. 1993. Gekkonoid lizard taxonomy. International Gecko Society, San Diego, California. 245 pp.

Manamendra-Arachchi. K. 1997. Gecko! *Sri Lanka Nature*. 1(1): 45-55.

Smith, M. A. 1935. The fauna of British India, including Ceylon and Burma. Reptilia & Amphibia. Vol. 11- Sauria. Taylor & Francis, London. 440 pp. Reprinted by Today & Tomorrow Printers & Publishers, New Delhi, 1974 and 1995.

Werner, W. L. 1982. The upper montane forest of Sri Lanka. *The Sri Lanka Forester*, Vol. 15, 119-35.

Wickramasinghe, M. & R. Somaweera 2002. Distribution and current status of the endemic geckos of Sri Lanka. *Gecko* 3(1): 2-13.

Plate 9

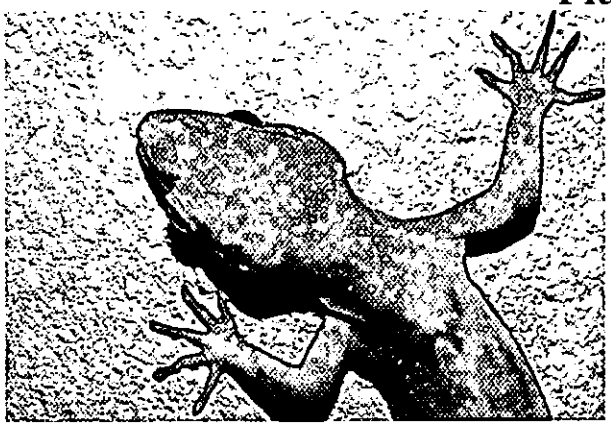


Figure 1. *Cyrtodactylus soba* (Photo: Usui Toshikazu)

Figure 2. *Cyrtodactylus soba*

Figure 3. *C. soba* hatchling wit white tail tip

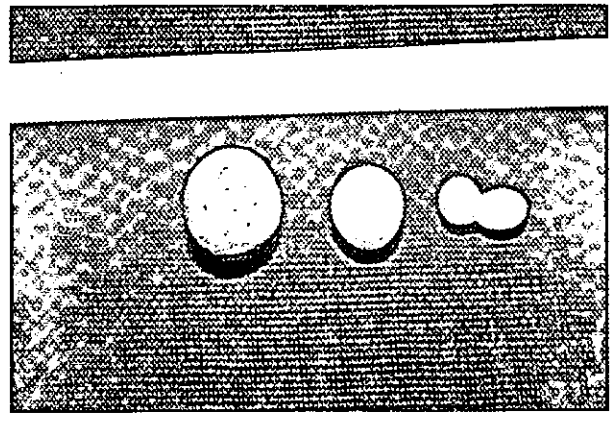


Figure 4. *C. soba* egg compared with other gecko eggs

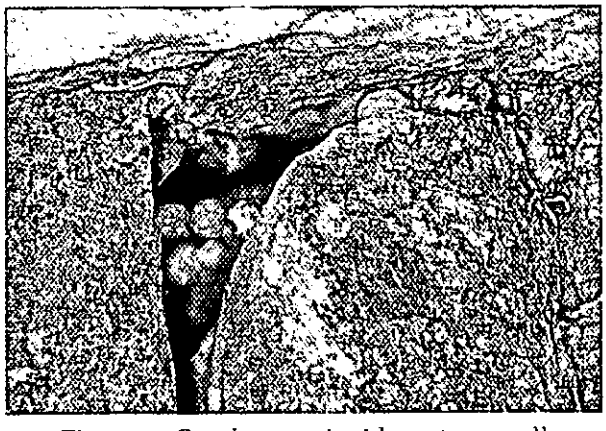


Figure 5. *C. soba* eggs inside a stone wall

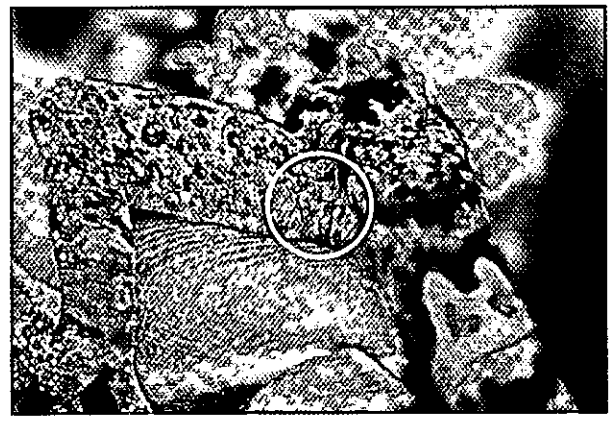


Figure 6. *C. soba* with chiggers

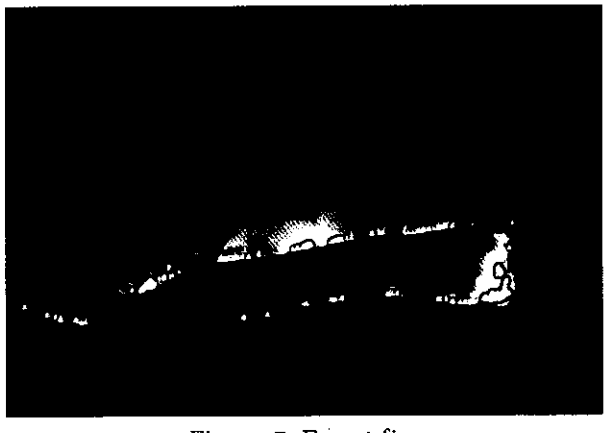


Figure 7. Forest fire

Figure 8. Burnt *C. soba*

Photographs: © Suraj Goonewardene and Anslem de Silva

The Diversity of the Dumbara Mountains (The Knuckles Massif, Sri Lanka): With special reference to its herpetofauna. *Lyriocephalus* Special issue, 2005 November, Volume 6 Numbers 1 & 2: 147
ISSN 1391–0833

SORT COMMUNICATION

OBSERVATIONS OF GECKO CANNIBALISM

Anslem de Silva[1], S. Goonewardene[2], J. Drake[2], & Aaron Bauer[3]

[1]15/1 Dolosbage road, Gampola, Sri Lanka. Email: kalds@sltnet.lk
[2]97, Battersea Park Road, London, SW9 4DU, UK. E-mail: hsr.wild@gmail.com (University of Edinburgh, UK)
[2]Creagard, Isle of Mull, PA75 6RA, UK. E-mail: jfdrake@gmail.com (University of Edinburgh, UK)
[3]Department of Biology, Villanova University, 800 Lancaster Avenue, Villanova, Pennsylvania 19085, USA. Email: aaron.bauer@villanova.edu

Geckos that are known from Sri Lanka in general are typically insectivorous, but some larger species (*Calodactylodes illingworthorum*, *Hemidactylus maculatus hunae* and *Cyrtodactylus* species) inhabiting the country are occasional predators on other vertebrates (Deraniyagala, 1953). During the Knuckles Expedition we observed on the wall of the hotel the researchers stayed one adult *Hemidactylus brookii* attacked another subadult *Hemidactylus brookii* and devoured the latter around 2000 hours from the tail side (Plate 5. Figure 4).

Acknowledgement: A. J. G. Burns for the photograph.

Literature cited

Deraniyagala, P. E. P. 1953. *A coloured atlas of some vertebrates from Ceylon. Vol.2 Tetrapod Reptilia.* Ceylon National Museums Publication.Ceylon Govt. Press. 101 pp.

The Diversity of the Dumbara Mountains (The Knuckles Massif, Sri Lanka): With special reference to its herpetofauna.
Lyriocephalus Special issue, 2005 November, Volume 6 Numbers 1 & 2: 149-159
ISSN 1391–0833

NOTES ON THE SNAKES INHABITING THE KNUCKLES MASSIF WITH SPECIAL REFERENCE TO *UROPELTIS MELANOGASTER* (GRAY, 1858) AND *UROPELTIS PHILLIPSI* (NICHOLLS, 1929)

Anslem de Silva[1], Suraj Goonewardene[2], Aaron Bauer[3], Christopher Austin[4], John Drake[2] & Panduka de Silva[1]

[1]15/1 Dolosbage road, Gampola, Sri Lanka. Email: kalds@sltnet.lk
[2]97, Battersea Park Road, London, SW9 4DU, UK. E-mail: hsr.wild@gmail.com (University of Edinburgh, UK)
[2]Creagard, Isle of Mull, PA75 6RA, UK. E-mail: jfdrake@gmail.com (University of Edinburgh, UK)
[3]Department of Biology, Villanova University, 800 Lancaster Avenue, Villanova, Pennsylvania 19085, USA. Email: aaron.bauer@villanova.edu
[4]Museum of Natural Science, Louisiana State University, 119 Foster Hall, Baton Rouge, LA 70803 USA. Email: ccaustin@lsu.edu
[5]Dept of Biological Sciences, Rajarata University of Sri Lanka

Keywords: Snakes, Knuckles, *Uropeltis*, *Rhinophis*, *Liopeltis calamaria*, threats.

Introduction

Ninety six species of snakes are recorded from Sri Lanka (de Silva, 1990, 2001). During the Knuckles Expedition 2004 and 2005, 33 (34 %) species of snakes were encountered inhabiting various locations of the Knuckles Massif. Of these 15 are endemic and two are geographical relicts. It is felt that more intensive field investigations would reveal the presence of more snake species, especially the fossorial species belonging to families Colubridae, Typhlopidae and Uropeltidae.

One of the first snakes to be describe from the Knuckles massif with a specific location (Gammaduwa) was *Uropeltis phillipsi* by Luscious Nicholls (1929) (Plate 10. Figure 1).

Field methods

The study was conducted from 23rd June to 23rd August 2004 and July to September 2005 In addition one of us (AdS) has been visiting the Knuckles infrequently during the past 20 years.

1. Three survey techniques were used: visual encounter survey (VES), patch sampling and sampling in large (20 x 20 m) leaf litter quadrats in the different vegetation habitats.
2. The GPS location and the altitude were recorded in all study locations.
3. The gender of the animal, length from the tip of the snout to the vent (SVL), and tail length were recorded in millimeters using a micromatic 1m steel tape. Reproductive status (gravid or not), presence of ecto-parasites were also recorded.
4. Stomach contents were checked only of road kill snakes.
5. When a snake was detected, atmospheric temperature, temperature of the microhabitat and body temperature were recorded using a digital thermometer (130 mm stainless steel sensor probe model ST-9263A/B/C).
6. The soil hardness of the microhabitat of fossorial species was measured using a penetrometer (pocket penetrometer model-STCL-3).
7. After recording the above data in a structured survey form, the animals were released back to the same locality in which they were found.

Results

The snake species observed during the Knuckles survey are listed in Tables 1, 2 and 3. Some ecological notes of these snakes are given under the respective snake in the species checklist.

Table 1
Snake species observed in the forest floor leaf litter quadrats: Knuckles 2004

Quadrat No & habitat	Altitude	Snake species
1 – Pine	1300	*Uropeltis melanogaster* (2 specimens)
5 – Pine	980	*U. melanogaster* (2 specimens)
8 – Pine	1300	*U. melanogaster* (2 specimens)
13 - Cardamom	1250	2 *U. melanogaster*, 1 *Haplocercus ceylonensis*, 1. *H. neap*
14 - Cardamom	1300	1f *U. melanogaster*, 1. *Aspidura trachyprocta* (gravid), *Hypnale hypnale*
19 – Cardamom	1179	*Boiga ceylonensis*
24 – *Acacia*	1095	*U. melanogaster* (3 specimens)
25 – *Acacia*	1095	*U. melanogaster* (2 specimens)
27 – *Acacia*	1095	*U. melanogaster* (1 specimens)
31 – *Acacia*	1095	*U. melanogaster* (1m, 2f, 1NS)
37 - Monsoon forest		*Hypnale hypnale*

Snake species observed in the Knuckles massif in 2004 and 2005

FAMILY BOIDAE Gray, 1825
SUB FAMILY PYTHONIDAE Fitzinger, 1826
Genus: *Python* Daudin, 1803

1. *Python molurus molurus* (Linnaeus, 1758). English: Indian python, Pimbura. Status: Not endemic.

Notes: We observed only one specimen at Illukumbura close to the Forest Office. Many villagers nevertheless informed us during the survey of its presence in the Knuckles.

FAMILY COLUBRIDAE.
Genus: *Ahaetulla* Link, 1807

2. *Ahaetulla nasuta* (Lacépède, 1789) (English: Green vine snake, Sinhala: Ahaetulla. Status: Not endemic)

Notes: Nineteen specimens were observed from various locations (altitude ranged from 277 to 1450 m) during the survey, suggesting that *Ahaetulla nasuta* was common in the Knuckles. There were 3 males (average total length 956 mm) and 12 females (average total length 876 mm). The weight of 4 specimens was taken, and this ranged from 12 to 39g. It was active during the morning hours (8:30 to 11:00 hours) on low vegetation along roadsides and footpaths. Five specimens were observed on vegetation by the roadside, and two were observed basking (thermoregulating) on tar roads in the morning around 0900 hours. They were observed for about 5 minutes and surprisingly did not attempt to escape into the vegetation, but preferred to stay on the warming tar road. Two distinct colour variations of *Ahaetulla nasuta* were observed at the Knuckles: specimens with a yellowish green ventral side, which is the common colour seen in most specimens throughout the island. The other colour observed was specimens with chocolate brown ventral side. The dorsal sides of both were leaf green. Deraniyagala (1955) records four colour morphs, including the chocolate brown ventral aspect one from Namunukula but the ones observed at Knuckles were slightly different colour. One specimen was a road kill and one specimen had fed on a *Cnemaspis* 40 mm long.

Genus: *Amphiesma* Duméril, Bibron & Duméril, 1854.

3. *Amphiesma stolatum* (Linnaeus, 1758). English: Buff striped keelback, Sinhala: Aharukuka. Status: Not endemic.

Notes: *Amphiesma stolatum* is a common species in plains close to aquatic habitats in the country. However, at Knuckles only two specimens were observed.

Genus: Aspidura Wagler, 1830

4. *Aspidura brachyorrhos* (Boie, 1827) English: Boie's roughside, Sinhala: Le madilla. Status: Endemic
Notes: This species was observed in North East Knuckles around Lakegala close to a marsh (app 600 m asl). This is the first record of this relict species from this area. Earlier one of us (AdS) observed *Aspidura brachyorrhos* at Wasgamuwa Wildlife Park, which is the northern most location for this reptile. Gans & Fetcho (1982) records *Aspidura brachyorrhos* from Gammaduwa (750 m).

5. *Aspidura trachyprocta* Cope, 1860. English: Common roughside, Sinhala: Dalawa madilla. Status: Endemic.
Notes: Six specimens within an altitude range of 1043 to 1550 m of this highly polymorphic snake was observed around Riverstone, Kobonila, and is the common species of the genus *Aspidura* at Knuckles. Gans & Fetcho (1982) records *Aspidura trachyprocta* from Gammaduwa.

Genus: *Boiga* Fitzinger, 1826
6. *Boiga ceylonensis* (Günther, 1858). English: Sri Lanka cat snake, Sinhala: Nidi mapila. Status: Not endemic.
Notes: Ten specimens were observed, 2 hatchlings and the rest adults. One was a male, 4 were females and the gender of the remaining 3 were not checked. These were observed inhabiting an altitude range of 313 to 1191 m, often in areas of anthropogenic habitats. The total length of the adults ranged between 247 and 776 mm with weights ranging from 26 to 36g. One female (770 m total length) was observed on a dead tree approximately 5 m above the ground at Pitawala Pathana (900 m). One adult female SV 348.5 and tail 165 mm long was run over by a vehicle and killed at Kobonila in July 2004.

7. *Boiga trigonata trigonata* (Schneider, 1802). English: Gamma cat snake, Sinhala: Ran mapila. Status: Not endemic.
Notes: Three adults, one female (total length 554 mm), and the gender of the other two were not identified .were observed in human habitation. One was foraging in a house at Kobonila at night. The altitude ranged from 500 and 1191 m. apparently, not common as *Boiga ceylonensis.*

Genus: *Chrysopelea* Boie, 1826
8. *Chrysopelea ornata ornata* (Shaw, 1802). English: Ornate flying snake, Sinhala: Malsara. Status: Not Endemic.
Notes: One large female was observed near Lakegala on the ground near a house.

Genus: *Coelognathus* Fitzinger, 1843.
9. *Coelognathus helena helena* (Daudin, 1803). English: Trinket snake, Sinhala: Katakaluwa. Status: Not endemic.
Notes: Observed one specimen run over by a vehicle and killed at Hunnasgiriya.

Genus: *Dendrelaphis* Boulenger, 1890
10. *Dendrelaphis bifernalis* (Boulenger, 1890). English: Boulenger's bronze back, Sinhala: Pandura haldanda. Status: Not endemic.
Notes: Though several were observed on low vegetation from various parts of the Knuckles only one were caught for identification purposes.

11. *Dendrelaphis caudolineolatus* (Günther, 1869). English: Gunther's bronze back, Sinhala: Viri haldanda. Status: Not endemic.
Notes: Four *Dendrelaphis caudolineolatus* (Plate 10. Figure 2). were observed. One dead female (SV = 462 and Tail = 275 mm) run over by road traffic was at Riverston. Stomach contents showed a partially digested frog. Two were encountered crossing roads near Corbett's Gap at different times. They were observed ranging between the altitudes of 951 and 1212m, with total lengths ranging from 737 to 914 mm and weights ranging from 20 to 52g.
One of the first reports of this snake from Knuckles was by Nicholls in 1932. Apparently, he had received many *Dendrelaphis caudolineolatus* of which the longest (915 mm) had been a gravid female from Mousakanda.

12. *Dendrelaphis tristis* (Daudin, 1803). English: Common bronze back Sinhala: Tura haldanda. Status: Not endemic.
Notes: Several specimens of this fast

moving common arboreal snake. were observed on low vegetation at altitudes ranging from 211 to 722 m. One gravid female, measured 984 mm in total length and weighed 51g.

Genus: *Haplocercus* Günther, 1858

13. *Haplocercus ceylonensis* Günther, 1858. English: The black spine snake, mould snake,
Sinhala: Kurunkarawala. Status: Endemic.
Notes: Three specimens (Plate 10. Figure 3) of this sub-fossorial snake were observed.
The project observed specimens inhabiting the altitude range of 1082 to 1250m. One early gravid female (SV = 297 mm and tail 55 mm) weighed 8g. Accounts of habits of this inoffensive snake is reported (de Silva, 1990).

Genus: *Liopeltis Fitzinger*, 1843

14. *Liopeltis calamaria* (Günther, 1858). English: Reed snake, Sinhala: *Punbariya.* Status: Not endemic.
Notes: This rear diurnal terrestrial snake is known to inhabit close to permanent water sources in forests and plantations (de Silva 1990). One adult male (267 mm) was observed at Knuckles at an altitude of 676 m in a similar habitat crossing a foot path (Plate 10. Figure 4). This is the first record of this species from the Knuckles.

Genus: *Lycodon* Boie, 1826

15. *Lycodon aulicus* (Linnaeus, 1758). English: Wolf snake, house snake, Sinhala: Alu radanakaya. Status: Not endemic.
Notes: Two specimen was recorded, an adult under a log in human habitation at an altitude of 261 m. The specimen was 288 mm in total length and weighed 12g. and a beautiful juvenile was observed at Kobonila. People consider it as a venomous snake, possibly due to its similar colouration to the highly venomous *Bungarus ceylonicus.*

16. *Lycodon striatus sinhaleyus* Deraniyagala, 1955. English: Shaw's wolf snake, Sinhala: Kabara radanakaya. Status: Endemic.
Notes: One adult female (223 mm in total length and weight 3.5g) with its fore body colouration similar to *Lycodon aulicus* was observed crossing a road at night in human habitation at an altitude of 248 m. It had 8 supralabials, 159 ventrals and 36 subcaudals where as *Lycodon aulicus* has 9 supralabials, 170-224 ventrals and 50-80 subcaudals (de Silva, 1990; PHDH de Silva, 1980; Deraniyagala, 1950).

Genus: *Macropisthodon* Boulenger, 1893

17. *Macropisthodon plumbicolor palabariya* Deraniyagala, 1955. English: The green keelback, Sinhala: Palabariya. Status: Endemic.
Notes: Three adults (measuring approximately 50 cm total length) run over and killed by road traffic was observed on different occasions close to Illukkumbura forest office.

Genus: *Oligodon* Boie, 1827

18. *Oligodon sublineatus* Duméril, Bibron & Duméril, 1854. English: Dumerul's kuki snake,
Sinhala: Pulli dath ketiya. Status: Endemic.
Notes: During the survey we observed 12 specimens, of which 5 were adult females - 1 of which was gravid (SVL 24.1 and Tail 4.2 mm long) observed in June on a foot path in a tea plantation at Kobonila. One was a male and the gender of the remaining 6 were not identified. The total length 6 measured ranged from 60 to 283 mm and weight from 6 to 13g. Specimens were recorded at altitudes ranging from 434 to 1136m, in lower montane, riverine and tropical mixed evergreen forests as well as in areas of anthropogenic activity such as human agriculture. Specimens were usually found under rocks and logs and in leaf litter.

Genus: *Ptyas* Fitzinger, 1843

19. *Ptyas mucosa maximus* (Deraniyagala, 1955). English: Rat snake, Sinhala: Gerandiya. Status: Endemic.
Notes: Observed a large male SV 169 cm and tail 35 cm along the road close to Maningala. Some boys in a near by house had attacked it. This common snake was observed from various parts of the Knuckles, but not collected.

Genus: *Xenochrophis* Günther, 1864

20. *Xenochrophis asperrimus* (Boulenger, 1891). English: The checkered keelback, Sinhala: Diya polonga, Diya bariya. Status: Endemic.
Notes: Several large specimens were observed in lowland streams, including one juvenile under a stone a few meters away from a stream in Kobonilla.

21. *Xenochrophis piscator piscator* (Schneider, 1799). English: The Checkered keelback, Sinhala: Diya naya, Diya bariya. Status: Not endemic.
Notes: This water snake is common in other parts of the country, however, at Kncukels we observed only a few.

FAMILY ELAPIDAE
Genus: Bungarus Daudin, 1803
22. *Bungarus caeruleus* (Schneider, 1801). English: The common krait, Sinhala: Thel karawala. . Status: Not endemic.
Notes: *Bungarus caeruleus* was observed in the northeast drier parts of the Knuckles Massif (Lakegala – Hettipola area and Laggala Pallegama). One female specimen (total length = 774 mm and weight = 89g) was observed inside an abandon hut in a paddy filed (altitude of 113 m) around 2000 hours.

23. *Bungarus ceylonicus ceylonicus* Günther, 1864. English: Sri Lanka (= Ceylon) krait, Sinhala: Madu karawala. Status: Endemic.
Notes: Though we observed only one juvenile, we were informed that many have seen this snake. At a Buddhist temple in Kobonila, a priest showed us photographs he had taken inside the temple of a large adult *Bungarus ceylonicus* swallowing another *Bungarus ceylonicus*. The Forest office at Deenstone too has a few preserved specimens collected from the area. One of the first reports of this snake from the Knuckles was by Nicholls in 1932 of a 109 cm long specimen from Mousakanda, Gammaduwa.

FAMILY TYPHLOPHIDAE Merrm, 1820.
Genus: *Ramphotyphlops* Fitzinger, 1843
24. *Ramphotyphlops braminus* (Daudin, 1803). English: Common blind snake, Sinhala: Dumuta kanaulla. Status: Not endemic.
Notes: Several observed.

Genus: *Typhlops*, Oppel, 1811
25. *Typhlops porrectus* Stoliczka, 1871.
Notes: This rare snake was discovered during the survey underneath large boulders in riverine forest and montane evergreen forests (Plate 10. Figure 5).

26. *Typhlops* species
Notes: Two specimens of blind snake were found which could not be identified using the available identification keys. Presently molecular and alpha taxonomy of this snake is being investigated.

FAMILY UROPELTIDAE Müller, 1832
Genus: *Rhinophis* Hemprich, 1820
27. *Rhinophis philippinus* (Cuvier, 1829). English: Cuvier's earth snake, Sinhala: Cuvierge walga ebaya. Status: Endemic.
Note: This fossorial snake was common in the Northeast part of the Knuckles. The project recorded 11 specimens, all of which were adults. Three were females; 4 were males; the gender of the remaining 4 not identified. One of the females was gravid. Of those measured, the total length ranged from 250 to 255 mm, and the weight from 3 to 7g. The specimens were observed under rocks and logs, inhabiting soil and root systems, with pentrometer readings ranging from 0.5 to 1.7. They were found in human, agriculture, lower montane, riverine and tropical mixed evergreen forests. At some places (Mimure) 3 specimens were found inside humus at depth of 4 cm together.

28. *Rhinophis* species
Note: A reddish coloured *Rhinophis* (Plate 10. Figure 6) had been observed by the staff of Hunas Falls Hotel, Elkaduwa around the farm area of the hotel (Personal communication, Nayanapriya Wijaya Bandara, October, 2005) This is listed in the present paper (as photographs of the specimen and the habitat was given to the first author though the actual specimen was not observed.

Genus: *Uropeltis* Cuvier, 1829

29. *Uropeltis melanogaster* (Gray, 1858) English: Black shield tail, Sinhala: Kaluwakatulla. Status: Endemic.

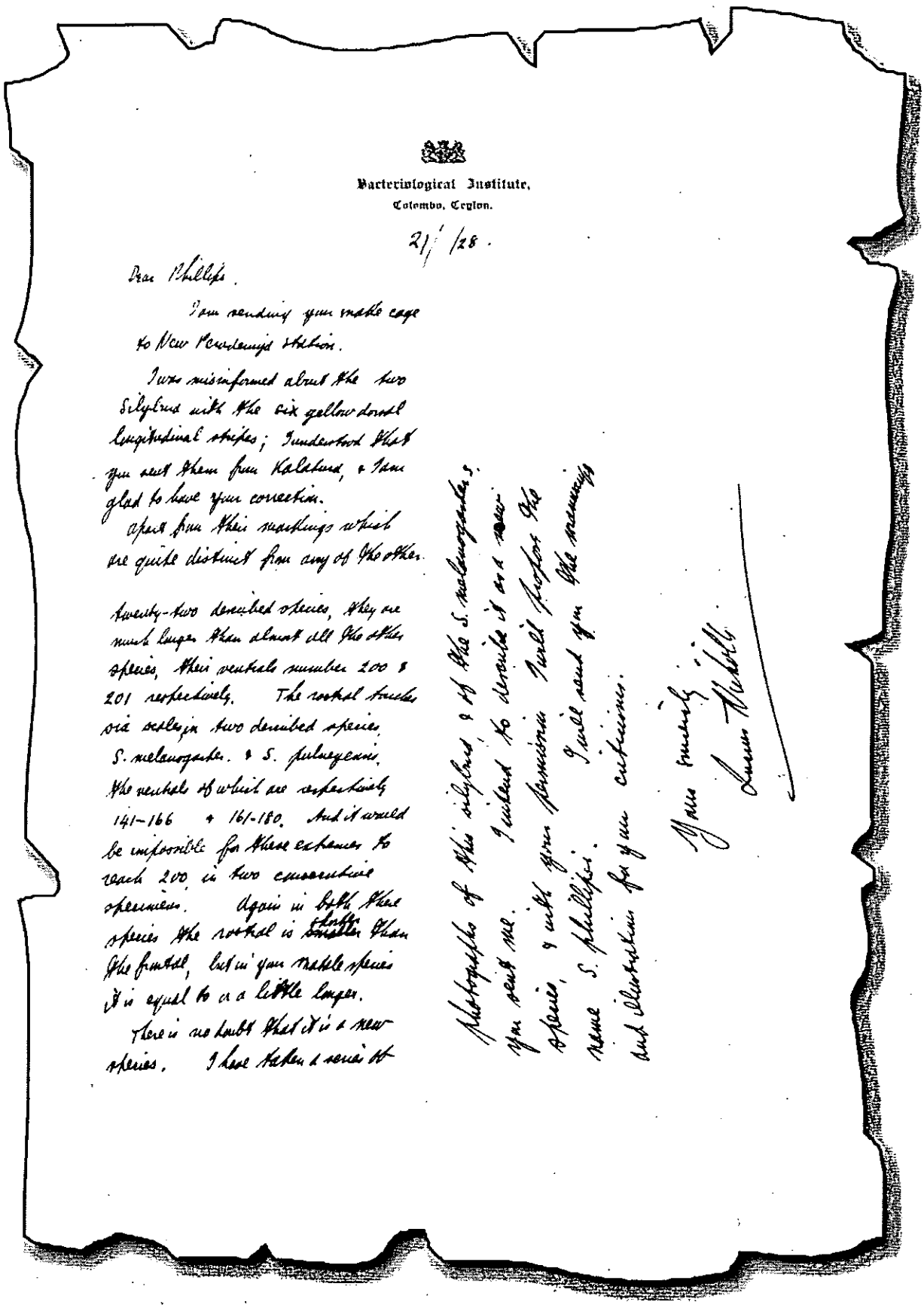
Notes: During the Knuckles Expedition we observed that *Uropeltis melanogaster* (Plate 10. Figure 7) to be dominant snake species inhabiting the south, western and central parts of the Knuckles. Nearly 50 specimens were seen, of which measurements of 36 specimens (32 adults and 3 sub-adults and 1 juvenile) with a snout vent length range of 150 to 275 mm inhabiting many parts of the Knuckles Massif from 900 to 1300 m were observed. The temperature in the microhabitat was usually 1 to 3 degrees centigrade less than the atmospheric temperature. During the visual encounter survey 17 *U. melanogaster* specimens were observed in montane forests, riverine forests, monoculture plantations (cardamom, pine and acacia) and home gardens. On several occasions, we observed this nocturnal reptile being attacked by ants and killed on footpaths and on the forest floor in the morning. We observed three gravid females in August. One of these was dead when first seen (possibly attacked by ants). This specimen when dissected contained three well developed foetuses. Stomach contents of some contained earthworms. From India, Rajendran (1985) reports an analysis of stomach contents of 12 uropeltid species and all contained 80 to 90 % earthworms. Although it is considered a fossorial species, all except one were found underneath boulders or rocks above the humus. Only one specimen was found inside the soil, 5 cm deep. It is an inoffensive snake and the specimens handled did not attempted to bite. However, some defensive behaviour such as knotting, expelling foul smelling excreta, and increase in the rate of protrusion of the tongue was observed in all. Some people at Knuckles believe that when a uropeltid knots around one's finger, it will only be possible to remove the snake by cutting the finger or by killing the snake. *Uropeltis melanogaster* inhabits the rich cool humus of mid-elevational wet semi-evergreen forests, mid-elevational dry-evergreen forests and montane wet-evergreen forests (cloud forest) of the Knuckles. However, due to clearing of major portions of these natural forests during the past two centuries for coffee, tea and cardamom plantations, it appears that this reptile has adjusted itself to live in these degraded and fragmented habitats. It is also found in the pine and *acacia* plantations, which lack both the rich humus and the moist cool conditions of an evergreen forest. Nevertheless, 17 of 19 specimens were observed within pine and *acacia* plantations perhaps demonstrating their adaptability to live in these degraded habitats.

30. *Uropeltis phillipsi* (Nicholls, 1929) (English: Phillips's shield tail, Sinhala: Iriwakatulla. Status: Endemic).

Notes: *Uropeltis phillipsi* was first described by Lucius Nicholls in 1929 under the name *Silybura phillipsi*. It was named in honour of W. W. A. Phillips (famous mammal expert and naturalist) who found the specimen in east Matale hills (Meniankanda Group, Gammaduwa). Original correspondence between Nicholls and Phillips regarding the naming of the snake is in the possession of the first author (Figure. 1). *Uropeltis phillipsi* is strikingly marked and colored with yellow and black markings (Plate 10. Figure 1).. Like most species of uropeltids, this species is inoffensive. However, when first collected and handled it has never attempted to bite but some defecate and smear the highly offensive smelling faecal matter on its body as well as on the fingers. In August 2004, we observed five specimens in a cardamom estate bordering a degraded montane forest at Gammaduwa at an altitude of 940 to 1115 m. All were found under rocks measuring 50 x 60 cm. The specimens were found between the stone and the humus. The temperature of the microhabitat was 21°C whilst the outside temperatures ranged from 28.4°C to 22.5°C (average 25°C). The penetrometer readings at the four locations ranged from 1 to 2.25. The snout vent lengths ranged from 190 to 268.

FAMILY VIPERIDAE Oppel, 1811

Genus: *Hypnale Fitzinger*, 1843



Bacteriological Institute,
Colombo, Ceylon.

21/ /28.

Dear Phillips.

I am sending your snake cage to New Peradeniya station.

I was misinformed about the two Silybura with the six yellow dorsal longitudinal stripes; I understood that you sent them from Kalatura, & I am glad to have your correction.

Apart from their markings which are quite distinct from any of the other twenty-two described species, they are much larger than almost all the other species, their ventrals number 200 & 201 respectively. The rostral touches six scales in two described species, S. melanogaster & S. pulneyensis, the ventrals of which are respectively 141–166 & 161–180. And it would be impossible for these extremes to reach 200 in two consecutive specimens. Again in both these species the rostral is ~~smaller~~ shorter than the frontal, but in your snake species it is equal to or a little longer.

There is no doubt that it is a new species. I have taken a series of photographs of this silybura & of the S. melanogaster & you sent me. I intend to describe it as a new species, & with your permission I will propose the name S. phillipsi. I will send you the manuscript and illustrations for your criticisms.

Yours sincerely,
Lucius Nicholls

Figure 1
Letter sent by Lucius Nicholls to W. W. A. Phillips regarding *the naming of U.phillipsi.*

31. *Hypnale hypnale* (Merrem, 1820).
English: The Merrem's Hump nose viper, Sinhala: Polonthelissa. Status: Not endemic.
Notes: This snake is responsible for snake bites, especially of tea and cardamom plantation workers. Thus, cardamom and tea plantation workers kill it on sight. During the Kncukels expedition 2004 and 2005, 28 specimens were observed, of these 12 were females, 8 were males and the gender of a further 8 not identified. Two females were gravid.

32. *Hypnale nepa* (Laurenti, 1768) (English: Millard's hump-nosed viper, Sinhala: Mukalan thelissa. Status: Endemic).
Notes: This snake was observed in forest areas including cardamom plantations, at the base of cardamom bushes among leaf litter, stones and decaying logs. Thus, cardamom and tea plantation workers killed this snake on sight. The male has a curious habit of keeping its tail end curled up like a shepherd's hook. Five specimens were observed.

Genus: *Trimeresurus* (Lacépède, 1804)
33. *Trimeresurus trigonocephalus* (Donndorff, 1798) (English: Green pit viper) Sinhala: Pala polonga. Status: Endemic.
Notes: The green pit viper is common and widely distributed in the Knuckles Massif. This may be because it is a highly prolific breeder, which produces quite a substantial clutch of hatchlings (de Silva, 1983a). In Knuckles the green pit viper lives in forests as well as low shrubs (cardamom and tea). Although it is a nocturnal species, it was observed to be active at Knuckles during the day. All specimens were observed on shrubs and low vegetation (tea and cardamom). A large female was observed on a tea bush around 10:00 h near Kobonila. Although the green pit viper is considered a slow and a sluggish species, we were amazed at how quickly it moved on the tea bushes. Once, on the trail to Lakegala, we came across a juvenile of about 1.5 m above the ground hanging onto a branch of a jak tree (*Artocarpus hetrophyllus*) around 10:00 h highly exposed to the sun. Once, a large female was observed around 11:00 h on the grass (30 cm tall) by the side of the road to Mimure passing Corbett's Gap, exposed to sunlight. Apparently, most specimens we observed were exposed to the morning sun; we observed a similar pattern in the other green coloured snake *Ahaetulla nasuta*. This suggests that the snake was thermoregulating, in fact checking air, body surface and cloacal temperatures using the digital thermometer (130 mm stainless steel sensor probe model ST-9263A/B/C) showed that the cloacal temperature was 3-4 degree centigrade higher than the air temperature. We observed several reptile species at Knuckles thermoregulating, including *Ceratophora tennentii* (de Silva *et al* 2005a in this volume). Although several colour variations of *Trimeresurus trigonocephalus* were observed in other parts of the country (de Silva, 1982), at Knuckles, of the 8 specimens we observed except one (Plate 10. Figure 8) all were of the standard colour patterned specimens. During the Knuckles expedition, one tea estate laborer (woman) informed us that she had been bitten by the green pit viper on five different occasions while plucking tea. We also came across several more cases of green pit viper bite. Thus it accounts for a fair number of snake bites of plantation workers. Earlier studies have also shown that *Trimeresurus trigonocephalus* ranks fifth in position for snakebite in humans (de Silva, 1983b).

Threats: Killing and road kills of snakes
Snakes, both venomous and non-venomous, are widely killed in Sri Lanka either through fear and ignorance or as a precautionary measure against snakebite. The high incidence of snakebite morbidity and mortality in Sri Lanka is the major contributory factor for this attitude (de Silva, 1990). A survey in the Knuckles showed that 98% of the respondents had killed snakes perhaps as 63% of the respondents family members had been bitten by snakes.

Field observations conducted in the Knuckles Massif showed that poisonous as well as non poisonous snakes were killed mainly during forest clearance and land preparation on tea estates and cardamom fields. Some of these snakes were Trinket

snake (*Coelognathus helena*), common kukri snake (*Oligodon* species), wolf snake (*Lycodon aulicus*), mildly venomous snakes such as the cat snakes (*Boiga ceylonensis* and *B. trigonata*) and the moderately venomous green pit viper (*Trimeresurus trigonocephalus*). Furthermore, during the survey period we observed four species of snakes (*Ahaetulla nasuta, Boiga ceylonensis, Coelognathus helena* and *Dendrelaphis* species) killed by road traffic. We also observed *Trimeresurus trigonocephalus, Ahaetulla nasuta* and *Ptyas mucosus* which were almost killed by vehicles while crossing the road. We feel that there may be even more snakes run over and killed at Knuckles than those observed, since snakes that are run over at night are invariably eaten by scavenging animals. Several instances of scavenging on road killed agamids, tortoises and amphibians were observed.

Table 2. Snakes observed at Knuckles Massif by various authorities

Snake species	Ginige, 1994	IUCN & Forest Dept. 1994	Rathnayake *et al*, 1999	Bambaradeniya & Ekanayake, 2003	Present Study 2005
Python molurus	Observed	Observed	Not	Observed	Observed
Cylindrophis maculatus	Not	Not	Not	Observed	Not
Ahaetulla nasuta	Observed	Observed	Observed	Observed	Observed
Ahaetulla pulverulenta	Not	Not	Not	Observed	Not
Amphiesma stolatum	Not	Not	Not	Observed	Observed
Aspidura brachyorrhos	Not	Not	Not	Not	Observed
Aspidura trachyprocta	Observed	Observed	Not	Not	Observed
Balanophis ceylonensis	Observed	Observed	Not	Not	Not
Boiga barnesii	Not	Not	Not	Observed	Not
Boiga ceylonensis	Observed	Observed	Not	Observed	Observed
Boiga forsteni	Not	Not	Not	Observed	Not
Boiga trigonata	Not	Not	Not	Observed	Observed
Chrysopelea ornata	Not	Not	Not	Observed	Observed
Chrysopelea taprobanica	Not	Not	Not	Observed	Not
Coelognathus helena	Not	Not	Not	Observed	Observed
Dendrelaphis bifernalis	Observed	Observed	Observed	Observed	Observed
D. caudolineolatus					Observed
D. tristis	Observed	Observed	-	-	Observed
Haplocercus ceylonensis	Not	Not	Not	Not	Observed
Liopeltis calamaria	Not	Not	Not	Not	Observed
Lycodon aulicus	-	Observed	-	-	Observed
Lycodon osmanhilli	-	Observed	Not	Not	Not
Lycodon striatus	Not	Not	Not	Not	Observed
M. plumbicolor	Observed	Observed	Observed	Observed	Observed
Oligodon sublineatus	Observed	Observed	Not	Observed	Observed
Oligodon taneolatus	Observed	Observed	Not	Observed	Not
Ptyas mucosa maximus	Observed	Observed	Observed	Observed	Observed
Xenochrophis asperrimus	Observed	Observed	Not	Not	Observed
Xenochrophis piscator	Observed	Observed	Observed	Observed	Observed
Bungarus caeruleus	Observed	Observed	-	Observed	Observed
Bungarus ceylonicus	Observed	Observed	Not	Not	Observed
Naja naja	-	-	-	Observed	Not
R. braminus	-	-	-	Observed	Observed
Typhlops porrectus	Not	Not	Not	Not	Observed
Pseudotyphlops philippinus	Not	Not	Not	Observed	Not
Rhinophis blythi	Observed	Observed	-	Observed	Not
Rhinophis phillipinus	Not	Not	Not	Not	Observed
Rhinophis trevelyana	-	-	-	Observed	Not
Uropeltis melanogaster	Not	Not	Not	Not	Observed
Uropeltis phillipsi	Not	Not	Not	Not	Observed
Daboia russelii	Observed	Observed	Not	Observed	Not
Hypnale hypnale	Observed	Observed	Not	Observed	Observed
Hypnale neap	-	-	Observed	-	Observed
T. trigonocephalus	Observed	Observed	Observed	Observed	Observed

Discussion and recommendations

During the investigations 33 snake species were observed. We found that patch sampling and visual encounter studies were the most effective field methods for locating snakes because of their fondness for certain habitats (Table 1). Studies at Knuckles and other parts of the country indicate that these two field techniques were more effective than sampling inside the forest floor leaf litter plots. Several earlier authors included snakes in their lists of reptiles from Knuckles (Ginige, 1994; Bambaradeniya & Ekanayake, 2003; IUCN & Forest Department, 1994 and Rathnayake et al, 1999 (Table 2). However, the validity of some species observed by some of these authors needs to be confirmed. The present paper provides additional species from Knuckles together with some notes.

A survey on the "knowledge, attitude and practice" of some inhabitants of Mimure, Knuckles towards animals showed that ninety six percent have killed snakes. This may be because they could not identify a non venomous from a venomous snake, or perhaps due to the high incidence of snakebite (de Silva *et al*, 2005b in this volume). Thus it is important to conduct an awareness program amongst the people in the Knuckles, as non-venomous relict species were wrongly identified as highly venomous and killed.

The snakes killed by road traffic also need careful study. In addition, the number of daily visitors to the Knuckles as well as the increase in residents should be examined.

Acknowledgements

We wish to thank: Mr. Sarath Fernando, Director General, Forest Department for permission granted to (AdS, AB and CA) (FRC/5 and FRC/6) to conduct the above study. Director General, Department of Wildlife Conservation, Mr. H. D. Rathnayake for approvals (WL/3/2/1/14/12). The Forest Department officers at Loolwatte and Illukumbura for their friendly support throughout the study. Manel Goonasekera, Head Department of Biological Sciences, Rajarata University of Sri Lanka for her support from the inception of the project. University of Edinburgh, UK for the approval given (to University of Edinburgh students) and the generous grant. Royal Geographical Society of UK for the grant.. Polly Bramham, Alasdair Ford, Douglas Fraser , Laura Packham and A. J. G. Burns for their assistance.

Literature cited

Bambaradeniya, C. N. B., & S. P. Ekanayake. 2003 *A Guide to the Biodiversity of the Knuckles Forest Region.* IUCN, Sri Lanka Country Office, Colombo. 68 pp.

Bachman, E. S. 1985. Distribution and variability of the Sri Lankan pipe snake (*Cylindrophis maculatus*). *Journal of the Bombay Natural History Society*, 82(2): 322-327.

De Silva, Anslem.1982. Some colour variations of the Green pit viper (*Trimeresurus trigonocephalus*), *Loris*, 16(2): 61-63

De Silva, Anslem. 1983a. Reproductive habits of *Trimeresurus trigonocephalus* (Sonnini et Laterille), *The Snake*, 15(1): 16-21,

De Silva, Anslem.1983b. *Trimeresurus trigonocephalus* bites. *The Snake*, 15(2): 91-94

De Silva, Anslem. 1990. *Colour guide to the snakes of Sri Lanka*. R & A Publishing ltd., Portishead. 130 pp.

De Silva, Anslem. 2001. *The Herpetofauna of Sri Lanka: historical aspects and current status.* Ministry of Environment, 100 pp + 150 plates.

De Silva, Anslem., A. Bauer, C. Austin, R. Meek, S. Goonewardene, J. Drake, & M. M. Goonasekera. 2005a. *Ceratophora tennentii* Günther & Gray, in Tennent, 1861 (Reptilia: Agamidae) some notes on its ecology. *Lyriocephalus* Special issue, 2005 February, Volume 6 Numbers 1 & 2:

De Silva, Anslem., A. Bauer, C. Austin, S. Goonewardene, J. Drake, G. S. Samarawickrama & M. M. Goonasekera. 2005b. Some cultural traits and attitudes of the inhabitants of Mimure (in the Knuckles massif) towards local animals, with special reference to the herpetofauna. *Lyriocephalus* Special issue, 2005 February, Volume 6 Numbers 1 & 2:

Deraniyagala, P. E. P. 1955. *A Colored Atlas of some Vertebrates from Ceylon. Serpentoid Reptilia.* Ceylon national Museums, Colombo, vii + 107 pp.

Gans, C. & Fetcho, J. R. 1982. The Sri Lankan Genus *Aspidura* (Serpentes. Reptilia, Colubridae). *Annals of Carnegie Museum*, 51(14): 271-316.

Ginige, P. 1995. Reptile fauna of the Knuckles Range, Sri Lanka, *Lyriocephalus*. 1(1 & 2): 38–43.

IUCN & FOREST DEPARTMENT. 1994. *Management plan for the conservation of the Knuckles Forest (Phase 2)*, Forest Department, Battaramulla. p 61 + appendices. Nicholls, L. 1929. A New Species of Earth Snake of the Genus *Silybura*, *Spolia Zeylanica* 15(2): 153-155.

Nicholls, L. 1932. Notes on Ceylon Snakes, *Spolia Zeylanica*, 17(1): 39-40.

Rajendran, M. V. 1985. *Studies in uropeltid snakes.* Publications Division, Madurai University, 132 pp.

Rathnayake, N. D., A.N. Werasinghe, K. Amarasinghe, C. Gamlath, D. Rathnayake, C. Irrugalrathne & H. Wijesinghe. 1999. *An ecological study on flora & fauna of Knuckles range – Sri Lanka (Northern Region).* Youth Exploration Society of Sri Lanka, Peradeniya. 33pp. (mimeographed paper)

Plate 10

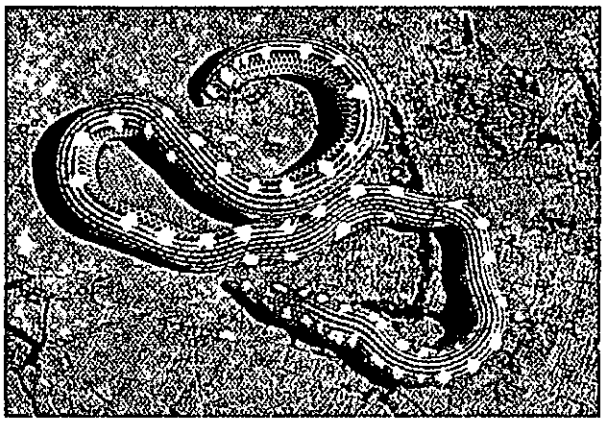


Figure.1. *Uropeltis phillipsi*

Figure. 2. *Dendrelaphis caudolineolatus*

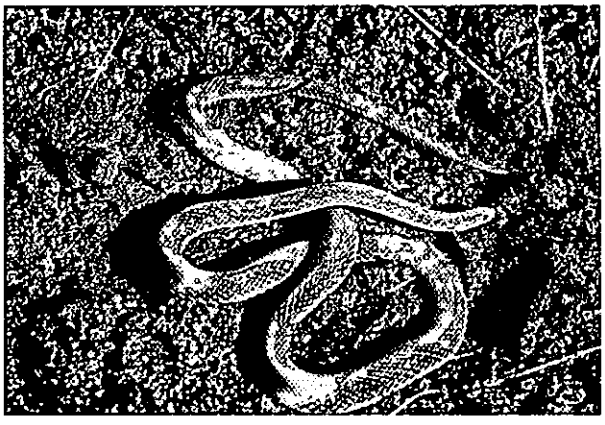


Figure. 3. *Haplocercus ceylonensis*

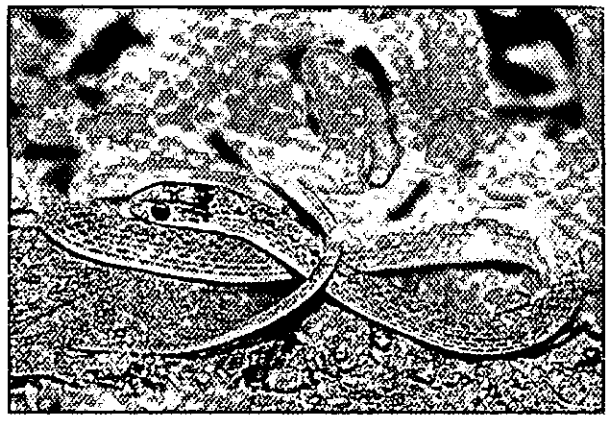


Figure. 4. *Liopeltis calamaria*

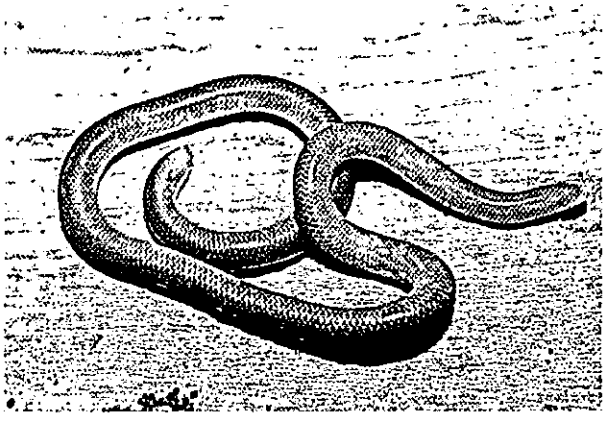


Figure. 5. *Typhlops porrectus*

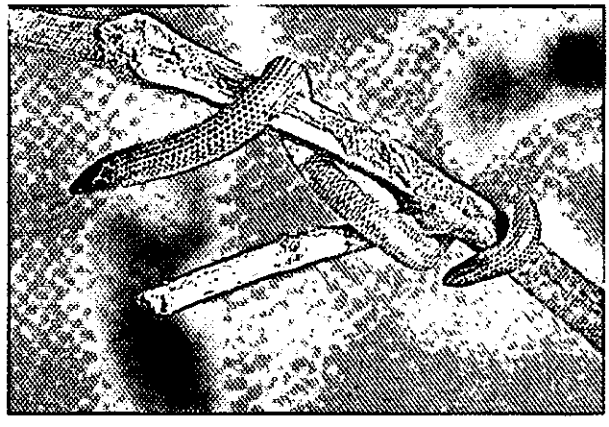


Figure. 6. *Rhinophis* species (Photo: N. W. Bandara)

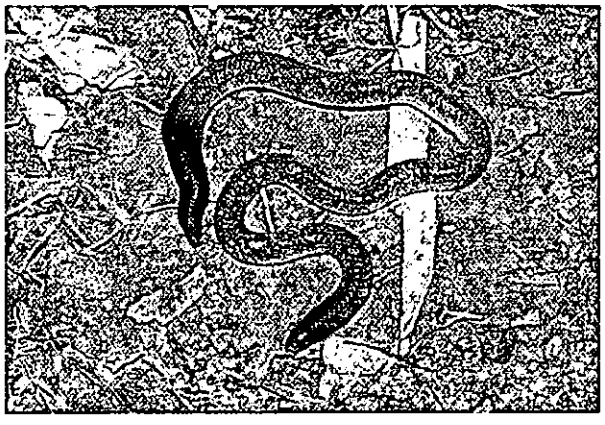


Figure. 7. *Uropeltis melanogaster* (?)

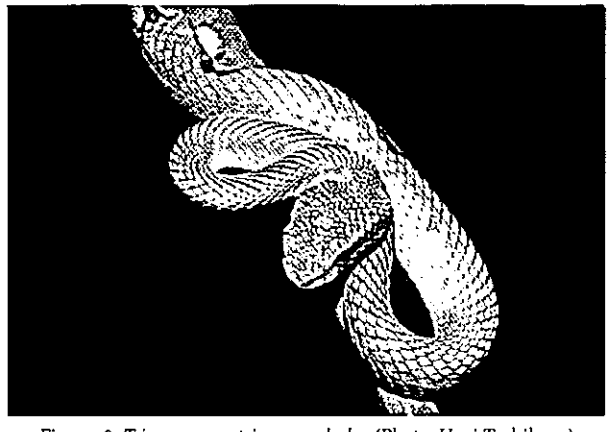


Figure. 8. *Trimeresurus trigonocephalus* (Photo: Usui Toshikazu)

Photographs: © Suraj Goonewardene and Anslem de Silva

The Diversity of the Dumbara Mountains (The Knuckles Massif, Sri Lanka): With special reference to its herpetofauna.
Lyriocephalus Special issue, 2005 November, Volume 6 Numbers 1 & 2: 163-169
ISSN 1391–0833

THE AMPHIBIAN DIVERSITY IN THE KNUCKLES MASSIF WITH SPECIAL REFERENCE TO THE RELICT SPECIES

Anslem de Silva[1], Suraj Goonewardene[2], John Drake[2], & Panduka de Silva[1]

[1]15/1 Dolosbage road, Gampola, Sri Lanka. Email: kalds@sltnet.lk
[2]97, Battersea Park Road, London, SW9 4DU, UK. E-mail: hsr.wild@gmail.com (University of Edinburgh, UK)
[2]Creagard, Isle of Mull, PA75 6RA, UK. E-mail: jfdrake@gmail.com (University of Edinburgh, UK)

Keywords: amphibian diversity, Knuckles, *Adenomus*, *Lankanectes*, *Nannophrys*, threats.

Introduction

The amphibian diversity and species richness of Sri Lanka is high. Scanning the current literature on valid amphibian species for the country, we see a total of 103 amphibian species are known from Sri Lanka (Dutta & Manamendra-Arachchi 1996; de Silva 2001; Bossuyt & Dubois 2001; Manamendra-Arachchi & Pethiyagoda 2005 and Meegaskumbura & Manamendra-Arachchi 2005). On going studies shows that this too was a gross under estimate, and the true figure may be as high as ca. 250 species (Pethiyagoda and Manamendra-Arachchi 1998). Thus, Sri Lanka becomes one of the richest countries in amphibian diversity per unit area of land (3.9 per 1,000 km^2 of land area) in the world. These figures are well ahead of the runner-up, Costa Rica with 2.75 amphibian species (Pethiyagoda and Manamendra-Arachchi 1998; Manamendra-Arachchi & Pethiyagoda 2005; and WHT work in progress on amphibian systematics). In fact recent studies using molecular phylogenies has shown that Sri Lanka has maintained an amphibian fauna that is distinct from that of Western Ghats (Bossuyt *et al.*, 2004).

The Knuckles Massif exhibits extensive variation in geology, altitude, vegetation, and climate. Thus, it offers ecological opportunities and ideal niches for amphibians. The recent description of five new amphibian species from a mere 10 km^2 forest at Corbett's Gap (1240 m), Knuckles exhibit this fact (Manamendra-Arachchi & Pethiyagoda 2005; Meegaskumbura & Manamendra-Arachchi 2005). Four earlier papers on Knuckles included lists of amphibian species the particular authors have observed in this ecosystem: 20 species by IUCN and Forest Department. (1994); 16 species by Rathnayake *et al.*, (1999); 20 species by Rathnayake (2001) and 20 species by Bambaradeniya & Ekanayake (2003) respectively. However, the validity of some of the amphibian species listed in these papers need verification.

The present paper records the amphibian species as well as the threats they face observed during the Knuckles expedition 2004 and 2005.

Methods

The principal methods used to locate amphibians were: visual encounter studies, patch sampling, leaf litter quadrate sampling, assessment of lentic and lotic habitats and canopy investigations. All animals were released back after investigations and photographing in the locality where they were collected

Results

The following amphibian species were identified in the Knuckles range of mountains. A few amphibians could not be identified using the available keys.

FAMILY: BUFONIDAE Gray, 1825
Genus: *Adenomus* Cope, 1860
1. *Adenomus kelaartii* Günther, "1858", 1859 (Kelaart's smooth finger toad = English; Kelartge siniduangili gemba = Sinhala). Status: Endemic, Endangered.

Notes: *Adenomus kelaartii* (Plate 11 Figure 1) was observed under decaying logs and

rocks, in leaf litter and along streams with rocky surfaces. Several froglets and adults were observed along streams with rocky surfaces. Although *A. kelaartii* is known from a wide range of habitats in the wet zone of the country (for details refer Dutta & Manamendra-Arachchi 1996) *A. kelaartii* was observed at Kandegama (750 m above sea level) during the Knuckles survey (2004 and 2005). We observed 1 to 4 adults under small rocks, decaying logs and along the banks of streams, whilst the froglets were observed in wet leaf litter along the streams.

Genus: Bufo Laurenti, 1768
2. *Bufo melanostictus* Schneider, 1799 (House toad = English; Geyi gemba = Sinhala). Status: Not endemic, Least concern.
Notes: *Bufo melanostictus* was found close to human habitations and in the forest floor, in monoculture plantations and degraded habitats. A common species.

FAMILY: MICROHYLIDAE Günther, 1858
Subfamily: Microhylinae , Günther 1858

Genus: *Kaloula* Gray, 1831
3. *Kaloula taprobanica* (Parker, 1934) (Common bull frog = English, Visituru rathu madiya = Sinhala). Status: Not endemic, Least concern.
Notes: *Kaloula taprobanica* though not observed during the expedition, the first author has reported it from Elkaduwa (de Silva & de Silva 1995) and Ginige reported it from Laggala-Pllegama (Ginige 1994).

Genus: *Microhyla* Tschudi, 1838
4. *Microhyla ornata* (Dumeril and Bibron, 1841) (Ornate narrow mouth frog = English, Visituru muvapatu madiya = Sinhala). Status: Not Endemic, Least concern.

Genus: *Ramanella* Rao and Ramanna, 1925
5. *Ramanella obscura* (Günther, 1864) (Grey-brown pugsnout frog = English; Alu dumburu motahombu madiya = Sinhala). Status: Endemic, Least concern.
Notes: This Microhylid was observed in the leaf litter in wet forests.

6. *Ramanella variegata* (Stoliczka, 1872) (White-bellied pugsnout frog = English; Badasudu motahombu madiya = Sinhala). Status: Not endemic, Least concern.
Notes: *Ramanella variegata* was observed in drier parts of the lowland north eastern side of Knuckles mainly in human habitations.

FAMILY: RANIDAE Rafinesque-Schmaltz, 1814
SUBFAMILY: RANINAE
Genus: *Lankanectes* Dubois & Ohler, 2001
7. *Lankanectes corrugatus* (Peters, 1863) (Corrugated frog = English; Vakarali madiya, = Sinhala). Status: Endemic, Vulnerable.

Notes: Many colour variations of *Lankanectes corrugatus* (Plate 11 Figure 2) were observed. Though this is the ancient and the only monotypic endemic subfamily in the country, its reproductive habits are poorly understood.

Genus: *Euphlyctis* Fitzinger, 1843
8. *Euphlyctis cyanophlyctis* Schneider, 1799 (Skipper frog = English; Utpatana madiya = Sinhala). Status: Not endemic, Least concern.
Notes: This ranid was widely distributed in the Knuckles. It was common in the rock pools at Pitawala Pathana (app 850 m, asl).

Genus: *Fejervarya* Bolkay, 1915
9. *Fejervarya kirtisinghei* (Manamendra-Arachchi & Gabadage, 1996) (Kirtisinghe's grass frog = English; Kirtisinghage thrunamadiya = Sinhala). Status: Endemic, Least concern.
Notes: This ranid was widely distributed in the Knuckles. It was common in lentic and lotic habitats.

10. *Fejervarya limnocharis* (Boie, 1835)(Common paddy field frog = English; Vel madiya = Sinhala). Status: Not endemic. Least concern.
Notes: A widely distributed species in the Knuckles.

Genus: *Nannophrys* Günther, 1869
11. *Nannophrys marmorata* Kirtisinghe, 1946 (Kirtisinghe's rock frog = English; Kirtisinghege galpara madiya = Sinhala). Status: Endemic, Endangered.

Notes: *Nannophrys marmorata* (Plate 11 Figure 3) is mainly confined to the Knuckles. During the survey we observed it from several localities ranging from 300 m to 1200 m above sea level (Emadawa, Lakegala, Kahatagolla, Pitawala Pathana) with small populations. They were found mainly inside narrow cracks in wet rock surfaces and under boulders along streams.

Genus: *Rana* Linnaeus, 1758

12. *Rana gracilis* Gravenhorst, 1829 (Sri Lanka wood frog = English, Lanka badimadiya = Sinhala). Status: Endemic, Least concern.

13. *Rana temporalis* (Günther, 1864)(Common Wood frog = English; Samanya badimadiya = Sinhala). Status: Not endemic, Least concern.
Notes: Several large adults were observed in streams in forests.

Genus: *Sphaeroteca*

14. *Sphaeroteca breviceps* (Schneider, 1799)(Band sand frog = English; Tunhiri valimadiya = Sinhala). Status: Not endemic, Least concern.

15. *Sphaeroteca rolandae* (Dubois, 1983) (Marble sand frog = English: Lapavan valimadiya = Sinhala). Status: Not endemic, Least concern.

SUBFAMILY: RHACOPHORINAE Hoffman, 1932

Genus: *Philautus*

16. *Philautus cavirostris* (Günther, 1869) (Tubercled Oriental shrub-frog = English; Hirigadu gasmadiya = Sinhala). Status: Endemic, Endangered.
Notes: Solitary specimens were observed on rocks and tree crevices close to streams in closed canopy forests. When it was disturbed it squirts a forceful spray of urine and jumps.

17. *Philautus fergusonianus* Ahl, 1927 (Ferguson's oriental shrub-frog = English; Fergasonge gasmadiya = Sinhala). Status: Endemic, Least Concern.
Notes: *Philautus fergusonianus* was common in forested locations of the Knuckles.

18. *Philautus fulvus* Manamendra-Arachchi & Pethiyagoda, 2005 (oriental shrub-frog = English; gasmadiya = Sinhala). Status: Endemic, Endangered.
Notes: This recently described species (Plate 11 Figure 4) was observed on moss covered rocks and logs.

19. *Philautus macropus* (Günther, 1869) (tree-frog = English; gasmadiya = Sinhala). Status: Endemic, Critically Endangered.
Notes: Though this frog was reported from Galaboda (central highlands) (Nayana Pradeep, 2001), recent review of species of the genus *Philautus* by Manamendra-Arachchi & Pethiyagoda (2005) show that *P. macropus* (Plate 11 Figure 5) is restricted only to the Knuckles and inhabit near streams between elevations 600 to 750 m. During the survey, we observed it at different locations.

20. *Philautus steineri* Meegaskumbura & Manamendra-Arachchi, 2005 (oriental shrub-frog = English; gasmadiya = Sinhala). Status: Endemic, Endangered.
Notes: This recently described species (Plate 11 Figure 6) was observed on moss covered rocks and logs.

21. *Philautus stuarti* Meegaskumbura & Manamendra-Arachchi, 2005 (oriental shrub-frog = English; gasmadiya = Sinhala). Status: Endemic, Endangered.
Notes: This recently described species (Plate 11 Figure 7) was common and observed on moss covered rocks and logs.

22. *Philautus sarasinorum* (Muller, 1887) (oriental shrub-frog = English; gasmadiya = Sinhala). Status: Endemic, Endangered.
Notes: This species was observed on moss covered rocks and logs near streams.

Genus: Polypedates Tschudi, 1838

23. *Polypedates cruciger* Blyth, 1852 (Common Hour-glass Tree-frog = English, Sulaba pahimbu gasmadiya = Sinhala). Status: Endemic, Least concern.

24. *Polypedates eques* Günther, 1858 (publ.1859) (Saddle tree-frog = English; Mukalan pahimbu gasmadiya Sinhala). Status: Endemic, Endangered.

25. *Polypedates maculatus* (Gray, 1834) (Chunam tree-frog = English; Hunu-gomara gasmadiya = Sinhala). Status: Not endemic, Least concern.
Notes: The species was observed in dryer lowlands of the Knuckles mainly in human habitations.

FAMILY: ICHTHYOPHIIDAE Taylor, 1968
Subfamily: Ichthyophiinae Taylor, 1968

Genus: *Ichthyophis* Fitzinger, 1826
26. *Ichthyophis glutinosus* (Linnaeus, 1758)(Common yellow band caecilian = English; Kaha hiridanda = Sinhala). Status: Endemic, Endangered.
Notes: *Ichthyophis glutinosus* (Plate 11 Figure 8) was observed under stones and logs along streams in forests as well as in tea plantations. A female with eggs was observed at Emadawa in July 2005.

Discussion and recommendations
The alarming trends in the decline of amphibians in other parts of the world is not fully understood (Bury & Corn, 1989; Clark, 1989). In Sri Lanka too, ongoing observations indicate the presence of potential threats to amphibians which may lead to a decline in population and extinction of species. However, the exact cause has yet to be identified. As regards amphibian extinctions in the world, Sri Lanka records one of the highest extinctions (19) (Stuart *et al.*, 2004, Manamendra-Arachchi & Pethiyagoda 2005; 2005; Pethiyagoda 2005 and Manamendra-Arachchi personal communication).

Recent studies indicate that Knuckles (see the present volume for papers) could be considered a biodiversity hotspot in the country. These studies also indicate the presence of new amphibian species inhabiting areas less than 10 km^2 of Knuckles (Meegaskumbura and Manamendra-Arachchi 2005). However, at Knuckles there is clear evidence that threats to this biodiversity are to a great extent caused by human activities. This will be detrimental to the eventual survival of some species with small populations. The human population around the Knuckles conservation forest area is increasing. In fact during the Knuckles expedition (2004 and 2005) several new constructions were observed in several places. Cincotta *et al.*, (2000) too indicate that human population densities is one of the highest among global hotspot countries.

Following are some specific threats that we observed at Knuckles, which may threaten some of the species that are mainly confined to Knuckles with extinction.

1. Bambaradeniya & Ekanayake (2003) reports that during their survey in 2001, they have observed *Adenomus kelaartii* from virtually the entire Knuckles. Though extensive surveys were conducted by us in the Knuckles for nearly six months in 2004 and 2005 after 3-4 years since Bambaradeniya & Ekanayake, we observed *Adenomus kelaartii* at a riverine habitat in Kandegama (750 m above sea level) and a riverine forest habitat close to Karandaketiya. The Kandegama riverine forest was virtually cleared up to the stream in many places for agricultural purposes over the past few decades. In addition, the farmers use agrochemicals (pesticides and fertilizer) widely. Draining of these toxic chemicals into the habitat of *Adenomus kelaartii* is inevitable. Thus, possible translocation of a small population of *Adenomus kelaartii* to another similar habitat with less or no human interferences should be considered.

2. *Nannophrys marmorata* was observed in eight highly fragmented localities. Of these eight locations, sampling indicated that except for one location all others had five to ten specimens of *Nannophrys marmorata*. Sampling was conducted during dry seasons (June, July, August and September 2004 and 2005). Other amphibian researchers (Manamendra-Arachchi 2005, personal communication) too have indicated the present rarity of *Nannophrys marmorata*.

3. *Lankanectes corrugatus* is widely distributed in the Knuckles from around 400 to 1200 m above sea level. Observations of the herpetofauna was conducted by the first author during the past 20 years during infrequent visits to the Knuckles which indicated appreciable populations of this frog. However, during the

Knuckles survey (2004 and 2005) less populations of *Lankanectes corrugatus* was observed when compared to what was observed a decade or so ago.

Dubois and Ohler (2001) reported that this well known 'Corrugated frog' is the only monotypic endemic subfamily (Ranidae: Lankanectinae) of frogs in the country. Furthermore, molecular evidence have shown that this ancient relict frog branched off before ranine and rhacophorine (Roelants *et al.*, 2004) frogs. Thus, this relict species needs immediate investigation.

The prevalent rates of application of insecticides, acaricides, rodenticides, fungicides, weedicides and fertilizer, especially in rice fields, vegetable plots and tea plantations in Knuckles have increased over the past decade. This decreases the insect population, an important food source for amphibians. Furthermore, these chemicals can make the water of paddy fields and the insects on which the anurans feed toxic. Similar observations have been made by Bhatti and Bhatti (1989) in India. The application of the common fertilizer urea, which is a rich source of nitrogen, may suffocate even adult frogs (Daniels 1991). This could be one reason for the decline in the large population of frogs.

Acknowledgements

We wish to thank: Mr. Sarath Fernando, Director General, Forest Department for permission granted to AdS, AB and CA (FRC/5 and FRC/6) to conduct the above study. Director General, Department of Wildlife Conservation, Mr. H. D. Rathnayake for approvals (WL/3/2/1/14/12). The Forest Department officers at Loolwatte and Illukumbura for their friendly support throughout the study.

University of Edinburgh, UK for funding and supporting Project Knuckles 2004 undergraduate research expedition (special thanks to the following University of Edinburgh Funds: Aranmore Memorial Travelling Scholarship, Davis Fund, James Rennie Bequest, Student Travel Fund, Weir Fund, William Dickson Travelling Fund and also British Student Travel Fund, Edinburgh No. 2 Fund, Gilchrist Educational Trust, Lindeth Charitable Trust, Peoples Trust for Endangered Species, Royal Geographical Society Expedition Research Grant (Gumby Award). BP (British Petroleum) for the generous grant.

Finally University of Edinburgh students: Polly Bramham, Alasdair Ford, Douglas Fraser, Laura Packham, and A. J. G. Burns and students from local universities: Rajarata University of Sri Lanka, South Eastern University of Sri Lanka (Chenkaladi), University of Jaffna, University of Sri Jayawardenepura, Kotte, and University of Peradeniya, Sri Lanka for their support in the field. Kelum Manamendra-Arachchi for commenting on the manuscript.

Literature cited

Bambaradeniya, C..N..B. & S. P. Ekanayake. 2003 *A Guide to the Biodiversity of the Knuckles Forest Region.* IUCN, Sri Lanka Country Office, Colombo. 68 pp.

Bhatti, S. K. & U.S. Bhatti. 1989. Entry of toxic environmental elements in frogs. Abstracts, *First World Congress of Herpetology*

Bossuyt, F. & A. Dubois. 2001. A review of the frog genus *Philautus* Gistel, 1848 (Amphibia, Anura, Ranidae, Rhacophorinae). *Zeylanica,* 6(1): 1-112.

Bossuyt, F., M. Meegaskumbura, N. Beenaerts, D. Gower, R, Pethiyagoda, K. Roelants, A. Mannaert, M. Wilson, M. Bahir, K. Manmendra-Arachchi, P. K. L. Ng. C. Schneider, O. V. Oommen & M. C. Milinkovitch. 2004. Local endemism within the Western Ghats-Sri Lanka biodiversity hotspot. *Science.*, Volume 306. 479-481.

Bury, R. B. & P.S. Corn. 1989. Declining amphibians in Western North America: Acid deposition, natural fluctuations, or unknown causes? Abstracts, *First World Congress of Herpetology*

Cincotta, R. P., J. Wisnewski & R. Engelman. 2000. Human populations in the biodiversity hotspots. *Nature,* 404: 990-992.

Clark, K. L. 1989. Interspecific variation in acid tolerance and its importance in determining the

responses of amphibians in North America to acidification of their breeding habits by acid deposition. Abstracts, *First World Congress of Herpetology*.

Daniels, R. J. R. 1991. The problem of conserving amphibians in the Western Ghats, India. *Current Science*, 60(11): 630-632.

de Silva, Anslem & P. de Silva. 1995. Some observations on *Kaloula taprobanica* (Amphibia: Anura: Microhylidae) in Sri Lanka. *Lyriocephalus*, 2(1 & 2): 48-51.

de Silva, Anslem. 2001. *The Herpetofauna of Sri Lanka: historical aspects and current status.* Ministry of Environment, 100 pp + 150 plates

Dubois, A. & A. Ohler. 1999. Asia and Oriental toads of the *Bufo melanostictus, Bufo scaber* and *Bufo stejengeri* Groups (Amphibia, Anura): a list of available and valid names and redescription of some name-bearing types. *J. of the South Asian Nat. Hist.*, 4(2): 133-180.

Dutta, S. K. & K. Manamendra-Arachchi. 1996. *The Amphibian Fauna of Sri Lanka*. Wildlife Heritage Trust of Sri Lanka, Colombo 1-230.

Ginige. P. 1994, Reptile Fauna of Knuckles range, Sri Lanka. *Lyriocephalus* 1 (1&2) 38-43

IUCN & Forest Department. 1994. *Management plan for the conservation of the Knuckles Forest (Phase 2)*, Forest Department, Battaramulla. p 61 + appendices.

Manamendra-Arachchi, K. & R. Pethiyagoda. 2005. The Sri Lankan shrub-frog of the genus *Philauts* Gistel, 1848 (Ranidae: Rhacophorinae), with description of 27 new species. *The Raffles Bulletin of Zoology*. Supplement 12.: 163-303. .
Meegaskumbura, M. & K. Manamendra-Arachchi 2005. Description of eight new species of shrub-frogs (Ranidae: Rhacophorinae: *Philautus*) from Sri Lanka.*The Raffles Bulletin of Zoology*. Supplement 12.: 305- 338. .

Nayana Pradeep, D. M. 2001. Amphibians observed around Galaboda waterfall, Sri Lanka: preliminary findings. *Lyriocephalus*, 4 (1 & 2): 101-106.

Pethiyagoda, R. & K. Manamendra-Arachchi. 1998. Evaluating Sri Lanka's Amphibian Diversity – *Occasional Paper, of Wildlife Heritage Trust of Sri Lanka* : No 2, 1 – 12

Pethiyagoda, R. 2005. Exploring Sri Lanka's biodiversity. *The Raffles Bulletin of Zoology*. Supplement 12.: 1-4.

Rathnayake, N. D, A. N. Weerasinghe, K. Amarasinghe, C. Gamlath, D. Rathnayake, C. Irrugalrathne & H. Wijesinghe. 1999. *An ecological study on flora and fauna of Knuckles range – Sri Lanka (Northern region)*. Youth Exploration Society of Sri Lanka, Peradeniya, 33 pages (mimeographed).

Rathnayake, N. D. 2001. Notes on some amphibians observed in Knuckles Range. *Lyriocephalus*, 4 (1 & 2): 121-123.

Roelants, K., J. Jiang & F. Bossuyt. 2004. Endemic ranid (Amphibia: Anura) genera in southern mountain ranges of the Indian subcontinent represent ancient frog lineages: evidence from molecular data. *Molecualr Phylogenetics and Evolution*. 31: 730-740.

Stuart, S. N., J. S. Chanson, N. A. Cox, B. Young, A. Rodrigues, D. Fischman & R. Walter. 2004. Status and trends of amphibian declines and extinctions worldwide. *Science*, Vol. 306: 1783-1786.

Table 1
Amphibian species observed during the present study compared with other studies

Amphibian species	IUCN & Forest Dept. 1994	Rathnayake *et al*, 1999	Bambaradeniya & Ekanayake, 2003	Present Study 2004 & 2005
Adenomus kelaartii	Not	Not	Observed	Observed
Bufo melanostictus	Observed	Observed	Observed	Observed
Kaloula taprobanica	Observed	Not	Observed	Observed
Microhyla ornatua	Observed	Not	Observed	Observed
Microhyla zeylanica	Not	Not	Observed	Not
Ramanella obscura	Observed	Observed	Observed	Observed
Ramanella variegata	Not	Not	Not	Observed
Euphlyctis cyanophlyctis	Observed	Not	Observed	Observed
Lankanectes corrugatus	Observed	Observed	Observed	Observed
Fejervarya kirtisinghei	Observed	Observed	Observed	Observed
Fejervarya limnocharis	Observed	Observed	Observed	Observed
Nannophrys marmorata	Observed	Observed	Observed	Observed
Rana gracilis	Observed	Not	Observed	Observed
Rana temporalis	Not	Observed	Observed	Observed
Sphaeroteca breviceps	Not	Not	Not	Observed
Sphaeroteca rolandae	Not	Not	Not	Observed
Philautus macropus	Not	Not	Not	Observed
Philautus cávirostris	Not	Not	Not	Observed
Philautus fergusonianus	Not	Observed	Observed	Observed
Philautus fulvus	Not	Not	Described 2005	Observed
Philautus steineri	Not	Not	Described 2005	Observed
Philautus stuarti	Not	Not	Described 2005	Observed
Philautus sarasinorum	Not	Not	Described 2005	Observed
Polypedates cruciger	Observed	Not	Not	Observed
Polypedates eques	Observed	Not	Not	Observed
Polypedates maculatus	Not	Not	Not	Observed
Ichthyophis glutinosus	Observed	Not	Not	Observed
Unidentified *Philautus sp.*	Not	Not	Not	Observed
Unidentified *Philautus sp.*	Not	Not	Not	Observed

Plate 11

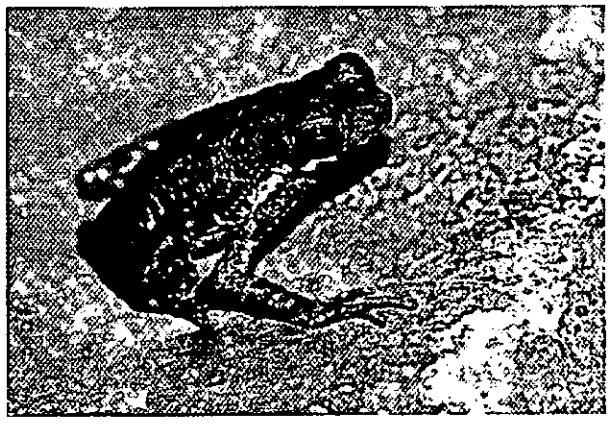


Figure 1. *Adenomus kelaartii*

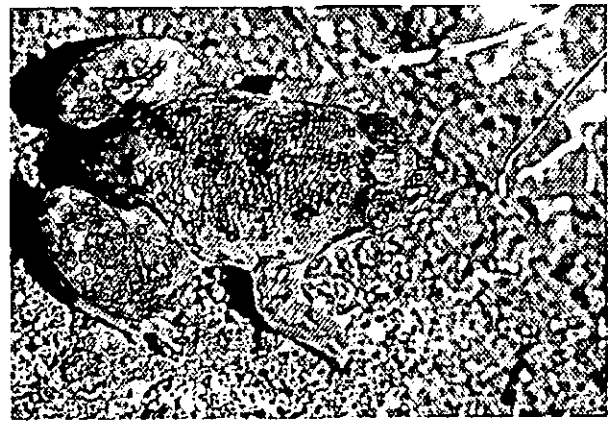


Figure 2. *Lankanectes corrugatus*

Figure 3. *Nannophrys marmorata*

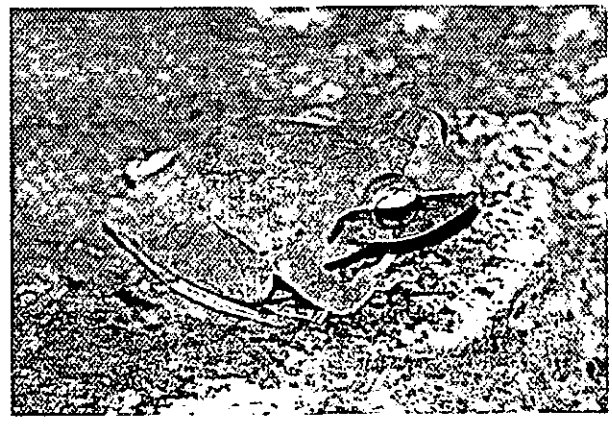


Figure 4. *Philautus fulvus*

Figure 5. *Philautus macropus*

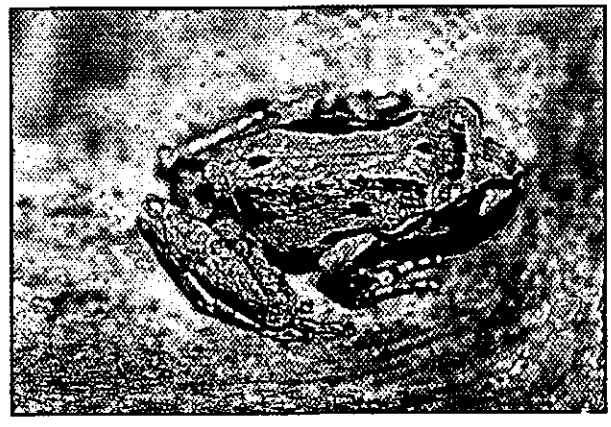


Figure 6. *Philautus steineri*

Figure 7. *Philautus stuarti*

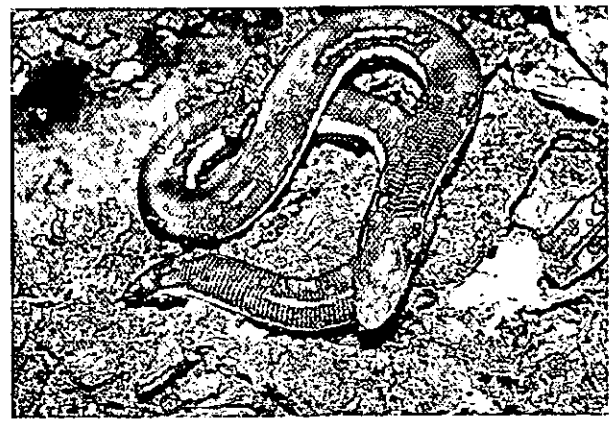


Figure 8. *Ichthyophis glutinosus*

Photographs: © Suraj Goonewardene and Anslem de Silva

The Diversity of the Dumbara Mountains (The Knuckles Massif, Sri Lanka): With special reference to its herpetofauna.
Lyriocephalus Special issue, 2005 November, Volume 6 Numbers 1 & 2: 173-177
ISSN 1391–0833

PRELIMINARY OBSERVATIONS ON SOME PARASITES OF GECKOS, SKINKS AND SNAKES INHABITING THE KNUCKLES MASSIF

Anslem de Silva[1], R. P. V. J. Rajapaksa[2], R.R.M.K.K. Wijesundera[2], A. Bauer[3], S.Goonewardene[4], J. Drake[4], C.C. Austin[5] & N. A. N. D. Perera[2]

[1]15/1 Dolosbage road, Gampola, Sri Lanka. Email: kalds@sltnet.lk
[2]Division of Parasitology, Faculty of Veterinary Medicine and Animal Science, University of Peradeniya, Sri Lanka jayanthar@pdn.ac.lk
[3]Department of Biology, Villanova University, 800 Lancaster Avenue, Villanova, Pennsylvania 19085, USA. Email: aaron.bauer@villanova.edu
[4]97, Battersea Park Road, London, SW9 4DU, UK. E-mail: hsr.wild@gmail.com (University of Edinburgh, UK)
[4]Creagard, Isle of Mull, PA75 6RA, UK. E-mail: jfdrake@gmail.com (University of Edinburgh, UK)
[5]Museum of Natural Science, Louisiana State University, 119 Foster Hall, Baton Rouge, LA 70803 USA. Email: ccaustin@lsu.edu

Keywords: Reptiles, Parasitic infection, *Physalopteroides* spp, Coccidial Oocyst, Knuckles.

Introduction

The study of parasites and the host-parasite relationship of reptiles of Sri Lanka has received attention for over a century. In the 19th century, it was Emerson Tennent who reported the presence of ticks of the family Ixodidae on reptiles (1861). In the 20th century there were additional reports of parasites from reptiles of the country (von Linstow, 1904; Clifford Dobell, 1910; Baylis, 1935; Burt, 1933 and others). However, the first significant contributions were made by Hilary Crusz and co-workers in their studies on the parasites of relict fauna of Sri Lanka (Crusz & Mills, 1970; Crusz & Sanmugasundaram, 1974; Crusz & Ching, 1975a; 1975b; Crusz & Nugaliyadde, 1978; Crusz & Daundasekera, 1988). These studies are still the most comprehensive parasitological investigations on the relict and endemic reptiles of the country to date. Since then, Rajapaksa *et. al.*, 1998, de Silva *et. al.*, 2004 and Nathanael *et. al.*, 2004 have worked on the parasites of geckoes and the star tortoise (*Geochelone elegans*) respectively.

The present paper deals with the parasites of geckos, skinks, and snakes inhabiting the Knuckles Massif.

Methods and materials

The main field techniques and methods employed to collect faecal samples were as follows:

While conducting patch sampling, visual encounter surveys, canopy investigations and quadrat sampling during the Knuckles 2004 Expedition, fæcal samples from geckos, agamids, skinks and snakes were collected into numbered, sterile plastic ampoules containing 10% formaldehyde solution. Invariably freshly captured reptiles defecate readily. As the stools emerged from the cloaca, an ampoule was held nearby to collect the faecal sample directly. The animals were released back to their original site of capture once the sample was obtained and measurements, gender and reproductive status of the specimens were recorded. The stool samples were taken to the Parasitology research laboratory of the Department of Veterinary Pathobiology, a part of the Faculty of Veterinary Medicine & Animal Science at the University of Peradeniya, for investigations and deposition for any future work.

Laboratory analysis

In the laboratory, the formaldehyde solution in the faecal sample containers was tipped off and the faecal sample was rinsed several times with distilled water.

Subsequently the sample was placed in a 1.5ml micro-centrifuge tube and centrifuged. Finally, the faecal pellet was re-suspended with 100 μl of distilled water. Thereafter 25 μl aliquot of the sediment (suspension) was used to prepare a smear on a glass slide. The smear was covered with a cover slip, and observed under a light microscope for parasitic stages, eggs and protozoan oocysts. The microscopic examination was repeated three times using 25 μl volumes of each sample. The helminth eggs were examined from a research microscope under 20 and 40 X magnification. Protozoan oocysts were examined to study their morphology under 40 X and 100 X magnification. Drawings of each parasitic stage were carried out using a Camera Lucida and all measurements were taken using a micrometer. Sizes of ten sample parasites from each specimen were measured and mean values were taken from the analysis.

Results

The results are summarized in Tables 1 to 4 and Plate 4 Figures 5 to 8.

Discussion

During the Knuckles Expeditions of 2004 and 2005 approximately 72 species of reptiles were observed, suggesting that this ecosystem is particularly species rich. A few of these reptiles, such as *Ceratophora tennentii, Nessia bipes, Chalcidoseps thwaitesii* and *Cyrtodactylus soba,* are confined to the Knuckles ecosystem, thus, it is vital to understand the health status of these animals. Information of these studies will be useful to future managers for conservation purposes. Though this is a preliminary investigation of the parasitic infections of the reptiles inhabiting the Knuckles Massif, it covers many reptiles frequently encountered in the Knuckles massif. It must also be mentioned that this is the first study conducted to understand the parasitic infections of several species of reptiles inhabiting the Knuckles Massif.

Our preliminary parasitological investigations indicate that there is a pattern in the distribution of parasitic infection according to the locality (Tables 1 to 4).

Following the pattern of parasitic infections observed in the study areas according to taxonomic group of reptiles (Tables 1, 2 &3). The faecal analysis of 20 geckos comprising 4 species revealed that 20% of samples were infected with either protozoan or nematode parasites. The nematode parasitic prevalence rate was 6.5% but the infection was of sub-clinical level. One sample showed a high nematode larvae count. Regarding gut protozoans, 11.8% of animals showed coccidian oocysts. Additionally, we observed a recently killed road mortality, a *Calotes calotes* with a heavy load of worms emerging from its mouth and nostrils. Upon dissection, a heavy mass of worms (*Physalopteroides* spp) was observed.

Of 34 skinks comprising about 10 species, nine were infected with Coccidial species. Three of these were also infected with nematode species. Of the nine snakes sampled one was infected with a nematode species.

As regards the locality, 47% of reptiles from areas around Deanstone, were infected with Coccidial species whereas 9.0% were infected with nematode species (Table 4). 20.0% of reptile specimens from the Kobonila area were positive for Coccidial Oocyst. In the Riverston area, 14.3% were positive for Coccidial oocysts. 14.3% of individuals from Lakegala and Mimure area were positive for Nematode infection. A geographic pattern of parasitic infection was observed in populations of the gecko *Calodactylodes illingworthorum,* inhabiting the Nilgala fire savannah (de Silva *et al.,* 2004).

Acknowledgments

We wish to thank: Mr. Sarath Fernando, Director General, Forest Department for permission granted to AdS, AB and CA (FRC/5 and FRC/6) to conduct the above study. Director General, Department of Wildlife Conservation, Mr. H. D. Rathnayake for approvals (WL/3/2/1/14/12). The Forest Department officers at Loolwatte and Illukumbura for their friendly support throughout the study.

Manel Goonasekera, Head Department of Biological Sciences, Rajarata University of Sri Lanka for her support from the inception of the project. University of Edinburgh, UK for the approval given (to University of Edinburgh students) and the generous grant. Royal Geographical Society of UK for a grant.

Aaron Bauer was supported by funds from the Department of Biology at Villanova University. USA.

Literature cited

Baylis, H.A. 1935. Two new parasitic nematodes from Ceylon. *Annals and Magazine of Natural History* (10) 16: 187-192.

Burt, D. R. R. 1933. *Oochoristica lygosomae* sp. nov. a Cestode from the lizards *Lygosoma punctatum*. *Spolia zeylanica* 18(1): 1-7

Crusz, H. & C.C. Ching. 1975. Parasites of the relict fauna of Ceylon. VI. More new helminths from amphibians and reptiles, with a new host-record and redescription of *Acantbocephalus serendibensis* Crusz and Mills, 1970. *Annales de Parasitologie (Paris)* 50(5): 531-558.

Crusz, H. & E. V. Mills. 1970. Parasites of the relict fauna of Ceylon. *Acanthocephalus serendibensis* sp. nov. from the Ceylon Horn - nosed lizard, *Ceratophora Stoddartii* Gray. *Annals de Parasitologie (Paris)* 45(1): 13-19

Crusz, H. & V. Sanmugasunderam. 1974. Nematodes from a Rhacophoid frog and reptiles of the hill country. *Annals de Parasitologie (Paris)* 48(6): 767-795.

Crusz, H. & I. Nugaliyadde. 1977. Parasites of the relict fauna of Ceylon; VII. General consideration and first host-parasite checklist; *C.R. Soc. Biogeor.* 477: 85-106.

Crusz, G. 1984. Parasites of endemic and relict vertebrates: a biogeographical review. In: *Ecology and Biogeography in Sri Lanka* (Ed.) C. H. Fernando. Dr. W. Junk Publishers, The Hague. pp.321-351.

Crusz, H. & D. M. A. K. Daundasekera. 1988. Parasites of the relict fauna of Ceylon. ix Helminths from burrowing scincine lizards. *Ann. Parasitol. Hum. Comp. Paris,* 63(6): 439-447.

de Silva, Anslem. R.P.V.J.Rajapakse, A. M. Bauer, C. C. Austin, S. Goonawardena, W. M. J. de Silva, Z. Hawke, V. Vanneck, A. Drion & M. M. Goonasekera. 2004. First report of parasites of *Hemidactylus maculatus hunae & Calodactylodes illingworthorum* (reptilia: Geckonidae) inhabiting the Nilgala fire savannah, Sri Lanka. *Lyriocephalus* special edition. Volume 5 (1 & 2): 199 – 205.

Dobell, C. C. 1910. On some Parasitic Protozoa from Ceylon, *Spolia Zeylanica*, 7(26): 65-87.

Nathanael S., S.M.M. Samarakoon, N.D. Warusamanna, R.P.V.J. Rajapakse and Anslem de Silva. 2004. Preliminary observations on parasites of captive star tortoises (*Geochelone elegans*) in Sri Lanka. *Testudo.* 6 (1): 46-51

Rajapaksa, R. P. V. J., V. Y. Kuruvita and Anslem de Silva. 1998. Preliminary study on external and internal parasites in *Geochelone elegans* (Star tortoise) in Sri Lanka. IN: *Biology and conservation of the amphibians, reptiles and their habitats in South Asia*. (Ed. Anslem de Silva). ARROS, 343-349.

Tennent, J. E. 1861. Snakes IN: Sketches of the Natural History of Ceylon with Narratives and Anecdotes,Longman, Green, Longman and Roberts,London.

von Linstow, O. 1904. Nematoda in the collection of the Colombo Museum. *Spolia Zeylanica* 1(4): 91-104, pls. i-ii.

Table 1
Parasites found in gecko species inhabiting the Knuckles

Kobonila	*Cyrtodactylus soba*	Coccidian oocysts
Kobonila Pine	*Geckoella triedrus*	None
Kobonila	*Cyrtodactylus soba*	None
Kobonila	*Cyrtodactylus soba*	None
Kobonila	*Cnemaspis* species	None
Kobonila	*Cyrtodactylus soba*	None
Kobonila	*Cyrtodactylus soba*	None
Kobonila	*Cyrtodactylus soba*	None
Lakegala	*Hemidactylus. Depresses*	None
Corbett's gap	*Geckoella triedrus*	None
Riverston	*Cnemaspis* species	None
Riverston	*Cnemaspis* species	None
Deenston	*Cnemaspis* sp.	Coccidian oocysts
Dotalugala	*Cyrtodactylus soba*	None
Dotalugala	*Cnemaspis* species	None
Rangala	*Cnemaspis* species	None
Lakegala	*Cyrtodactylus soba*	None
Kobonila	*Cyrtodactylus soba*	Coccidian oocysts
Kandegama	*Cnemaspis* species	Coccidian oocysts
Kobonila	*Cyrtodactylus soba*	None

Table 2
Parasites found in skinks species inhabiting the Knuckles

Dotalugala	*Lankascincus* species	None
Pine	*Lankascincus* species	None
Lakegala	*Lankascincus* species	None
Hunnasgiriya	*Lankascincus* species	Mite larval stage
Deenston	*Nessia bipes*	Nematode eggs & coccidian oocysts
Deenston	*L. fallax*	None
Deenston	*Lygosoma punctata*	Coccidian oocysts
Dotalugala	*Mabuya* species	None
Deenston	*Lygosoma punctata*	None
Kobonila	*Mabuya* species	None
Kobonila	*Lankascincus* species	Coccidian oocysts
Kobonila	*Chalcidoseps thwaitesii*	None
Alulengala	*Lankascincus* species	None
Lakegala	*Chalcidoseps thwaitesii*	None
Lakegala	*Chalcidoseps thwaitesii*	Nematode larva (highly positive)
Riverine	*Chalcidoseps thwaitesii*	None
Riverine	*Chalcidoseps thwaitesii*	None
Riverine Nitro	*Lankascincus* species	None
Corbett's gap	*Lankascincus* species	None
Corbett's gap	*Lankascincus* species	None
Corbett's gap	*Lankascincus* species	None
Karambaketiya	*Chalcidoseps thwaitesii*	None
Karambaketiya	Mabuya species	None
Rangala	*Lankascincus* species	None
Karambaketiya	*Chalcidoseps thwaitesii*	Nematode larva
Riverston	*L. taprobanensis*	None
Riverston	*L. taprobanensis*	None
Riverston	*Nessia bipes*	Coccidian oocysts
Riverston	*Lankascincus* species	None
Gammaduwa	*Nessia bipes*	None
Gammaduwa	*Nessia bipes*	Coccidian oocysts
Thangappuwa	*Lankascincus* species	Coccidian oocysts
Hunnasgiriya	*Lankascincus* species	Coccidian oocysts
Thangappuwa	*Lankascincus* species	None

Table 3
Parasites found in snake species inhabiting the Knuckles

Deenston	*U. melanogaster*	None
Deenston	*U. melanogaster*	Nematode larvae
Kobonila	*Boiga ceylonensis*	None
Mimure	*Ahaetulla nasuta*	None
Mimure	*A. nasuta* (female)	None
Corbett's gap	*Hypnale hypnale*	None
Riverston	*D.caudolinolatus*	None
Kobonila	*U. melanogaster*	None
Horakanda	*T. trigonocephalus*	None

Table 4
Parasites found according to the location of the reptile in the Knuckles

Riverston	*Nessia bipes*	Coccidian oocysts
Gammaduwa	*Nessia bipes*	Coccidian oocysts
Karambaketiya	*Chalcidoseps thwaitesii*	Nematode larva
Lakegala	*Chalcidoseps thwaitesii*	Nematode larva (highly positive)
Thangappuwa	*Lankascincus* species	Coccidian oocysts
Kobonila	*Cyrtodactylus soba*	Coccidian oocysts
Kobonila	*Cyrtodactylus soba*	Coccidian oocysts
Kobonila	*Lankascincus* species	Coccidian oocysts
Kandegama	*Cnemaspis* species	Coccidian oocysts
Deenston	*Lygosoma punctata*	Coccidian oocysts
Hunnasgiriya	*Lankascincus* species	Mite larval stage
Deenston	*Cnemaspis* sp.	Coccidian oocysts
Deenston	*Nessia bipes*	Nematode eggs & coccidian oocysts
Hunnasgiriya	*Lankascincus* species	Coccidian oocysts
Deenston	*U. melanogaster*	Nematode larvae

The Diversity of the Dumbara Mountains (The Knuckles Massif, Sri Lanka): With special reference to its herpetofauna.
Lyriocephalus Special issue, 2005 November, Volume 6 Numbers 1 & 2: 179-182
ISSN 1391–0833

SOME OBSERVATIONS OF THE MOLLUSKS OF THE KNUCKLES MASSIF

Anslem de Silva[1], K. B. Ranawana[2] & Suraj Goonewardene[3]

[1]15/1 Dolosbage road, Gampola, Sri Lanka. Email: kalds@sltnet.lk
[2] Dept. of Zoology, Faculty of Science, University of Peradeniya, Sri Lanka.
[3]97, Battersea Park Road, London, SW9 4DU, UK. E-mail: hsr.wild@gmail.com (University of Edinburgh, UK)

Keywords: Corillidae, Ariophantidae, Camaenidae, Glessulidae, Cycloporidae, Knuckles.

Introduction

The Knuckles range of mountains or the Dumbara hills is the home for several species of mollusks. Approximately 37 species are known from the Knuckles (Ranawana, 2005). Approximately 246 species of land snails are known in Sri Lanka, of which the majority (83%) are endemic (Naggs and Raheem, 2000).

The objective of the present survey was to record and identify the mollusks encountered during "Project Knuckles – 2004" as well as to assess and identify the threats faced by this group of invertebrates and their habitats.

Land snail research

Studies on land snails in Sri Lanka began more than 100 years ago (Collet, 1897; 1898, 1900; Blanford and Godwin-Austen, 1908; Gude, 1914, 1921). Although these works were mainly on the taxonomy and distribution of species, they remain as the pioneering work on the land molluscs of Sri Lanka. After this initial period work on land molluscs progressed very slowly until the late 1990's (Ratnapla, 1984; Ratnapla and Arudpragasam, (not dated) Breckenridge and Fallil, 1973). The late 1990's saw another phase of interest in ecological research on Sri Lankan land molluskcs (Morden et.al. 2003; Naggs et. al., 2003; Raheem et. al., 2000; Raheem and Butterworth, 1998, Ranawana, 2005). The Darwin Initiative (UK) land snail diversity project in Sri Lanka (1999 – 2002) was mainly responsible for initiating the second phase of ecological research on Sri Lankan land molluskcs.

Vegetation

The distinct vegitational habitats of the Knuckles: Humid tropical lowland semi-evergreen forests, Tropical sub-montane humid semi-evergreen forests, Tropical montane humid evergreen forests, Montane grasslands and Pygmy forests (de Rosayro 1956; Nanayakkara 1988; Ratnayake 2005 in this volume) offer ideal habitats for the land snails.

Field methods

Materials and Methods

Dry shell collections were made and washed carefully using a mild detergent and then air-dried. Then they were transferred into labeled polythene bags and stored in a storage cabinet.

The study was conducted for 45 days during the period 25th June, 2004 to 20th August 2004. Approximately 500 hours were spent in the field.

1. Four main survey techniques used were: visual encounter survey (VES), patch sampling, canopy sampling and sampling in large (20 x 20 m) leaf litter quadrats in different vegetation habitats.

2. The coordinates of all study sites, including the altitude, were recorded using a GPS instrument.
3. Mollusks were photographed using Olympus OM 30 camera using macro

and close-up lenses. Fuji Chrome and Fuji Colour, 400, 200 and 100 ASA, 36 exposure films were used.

Snail Identification

Identification was based on Naggs and Raheem (2002).

Results

During the investigations 25 species of mollusks (Table 1) were located and identified of which 13 species were endemic, Plate 12 Figures 1 to 8.

Discussion and recommendations

The Knuckles Massif is an important refugia for over 37 species of mollusks (Ranawana 2005). However, the mollusk fauna is facing many threats. These include: forest fires, which engulf several hectares and the use of pesticides and nitrogen fertilizer by tea estate workers. The long term effects are yet to be investigated.

Giragama & Madduma Bandara (1993) have shown that the annual rainfall of the Knuckles Range have decreased at Kobonila and Madugoda, but the biggest threat is due to deforestation and alteration of natural forests for plantations (Coffee, tea, and cardamom). Studies on the cardamom (*Elettaria cardamomum*) cultivation in the Knuckles Range have shown that the moisture content in the cardamom plots is low (Navaratne & Madduma Bandara, 1993) and that clay and organic mater value is also low (Navaratne & Madduma Bandara, 1995).

Acknowledgments

We thank Mr. Sarath Fernando, Conservator General, Forest Department, Director General, Department of Wildlife Conservation. The Forest Department officers at Deenstone and Illukumbura for their friendly support throughout the study. University of Edinburgh, UK for the approval given (to University of Edinburgh students) and the generous grant. Royal Geographical Society of UK for the grant.

We also thank V.A.M.P.K.Samarawickrama and E.M.A.B.Pushpakumara for their help.

Literature cited

Blanford, W. T. & H.H. Godwin–Austin. 1908. Mollusca, Vol. I, Testacellidae and Zontidae. *Fauna of British India*. Taylor and Francis, London.

Breckenridge, W.R., & S.F.M. Fallil. 1973. Histological observations on the reproductive system of *Achatine fulica* (Gastropods, Pulmonata, Stylommatophora). *Ceylon Journal of Science (Biological Science)*, 10 (2): 85 – 118.

Collet, O. 1897. Contribution to Ceylon Malacology. (1) The terrestrial Mollusca of Ambagamuwa. *Journal of the Royal Asiatic Society* (Ceylon Branch), 15 (48): 12 -22.

Collet, O. 1898. Contribution to Ceylon Malacology. (2) Description of a new helicoids land shell from the southern province. *Journal of the Royal Asiatic Society* (Ceylon Branch), 15 (49): 153 - 154.

Collet, O. 1900. Contribution to Ceylon Malacology. (3) The terrestrial Mollusca of Ambagamuwa (Part II). *Journal of the Royal Asiatic Society* (Ceylon Branch), 16 (51): 132 -139.

de Rosayro, R. A. 1956. The vegetation IN: P. G. COORAY. 1956. The Knuckles expedition. *Bulletin of Ceylon Geographical Society*, 10(3 & 4): 57-59

Giragama, W. M. G. B. & C. M. Madduma Bandara. 1993. Rainfall and relative humidity of the Dumbara Hills (Knuckles Range). *Annual Review 1992*, Institute of Fundamental Studies, Kandy, pp.72-73.

Gude, G.K. 1914. Mollusca, Vol. II. Trochomorphidae – Janellidae, Fauna of British India. Taylor and Francis, London, 520p.

Gude, G.K. 1921. Mollusca, Vol. III. Land Operculates (Cycloporidae, Truccatellidae, Assimineidae, Helicinidae). Fauna of British India. Taylor and Francis, London, 386p.

Morden, P., F. Naggs, K. B. Ranawana, S. Kumburegama, & B. Grimm. 2003. *A guide to the pest and exotic gastropods of Sri Lanka*. Department of Zoology, Natural History Museum, London: 10pp.

Naggs, F. & D. Raheem. 2000. *Land snail diversity in Sri Lanka*. The Natural History Museum, London. xiii + 243.

Naggs, F. & D. Raheem. 2003. The Darwin Initiative project on Sri Lankan land snails: patterns of diversity in Sri Lankan forests. *Molluscan Conservation and Biodiversity*, Special Publication Conchological Society, 8pp.

Naggs, F., D. Raheem, P. B. Mordan, B. Grimm, K. B. Ranawana, & N. P. S. Kumburegama. 2003. Ancient relicts and contemporary exotics: faunal change and survivorship in Sri Lanka's snail fauna. *Slugs & Snails: Agricultural, Veterinary & Environmental Perspectives*, British Crop Protection Council Symposium Proceedings No. 80, 103 - 108.

Navaratne, W. M. & C.M. Madduma Bandara. 1993. Cardamom cultivation in the Dumbara Hills (Knuckles Range) and its environmental impact. *Annual Review 1992. Institute of Fundamental Studies, Kandy*. pp. 73-74.

Navaratne, W. M. & C.M. Madduma Bandara. 1995. Categorization and analysis of plant and soil in two types of forest in the Dumbara Hills (Knuckles Range). *Annual Review 1994. Institute of Fundamental Studies, Kandy*. pp. 81-81.

Raheem, D. & T. Butterworth. 1998. A survey of land mollusk diversity in southwestern Sri Lanka. *Final Report of an Imperial College (University of London) expedition to southwestern Sri Lanka*, 1-34pp.

Raheem, D., T. Butterworth, C. Inglis, T.G. Mahesh Priyadarshana and L.J.K. Ranil Perara. 2000. *Land snail diversity in Sri Lankan rainforest remnants*, 29 + xxix.

Ranawana, K.B. 2005. Land mollusks in the Knuckles Region, Sri Lanka. (Unpublished report)

Ratnapala, R. 1984. Land snails: distribution and notes on ecology. In: C. H. Fernando. *Ecology and biogeography in Sri Lanka* (ed.). Dr. W. Junk Publishers, The Hague: 391 – 410.

Ratnapala, R. & K.D. Arudpragasam.(Not dated). *A checklist of land snails of Sri Lanka*. UNESCO: Man and Biosphere National Committee for Sri Lanka, Publication No.13. Natural resources, Energy and Science Authority of Sri Lanka: 10 pp.

Ratnayake, H. D. 2005. Some aspects of the vegetation of the Knuckles ecosystem The Diversity of the Dumbara Mountains (The Knuckles Massif, Sri Lanka): With special reference to its herpetofauna. *Lyriocephalus* Special issue, 2005 June, Volume 6 Numbers 1 & 2

Sub Class	Family	Species	Status	Locations												
				Mimure	Gammaduwa	Karadaketiya	Knuckles	Unknown	Niter Cave	Keenagomman a	Rangala	Knuckles Peak	Manigala	Laggala-pallegama	Kadegama	Reverston
Pulmonata	Acavidae	*Oligospira polei*	Endemic	+	-	-	+	-	-	-	-	-	-	-	+	-
	Corillidae	*Corilla erronea*	Endemic	+	-	-	+	-	-	-	+	-	-	+	-	-
	Corillidae	*Corilla gudei*	Endemic													+
	Corillidae	*Corilla sp.*		+	-	-	-	-	-	-	-	-	-	-	-	+
	Ariophantidae	*Euplecta semidecussata*		+	-	-	-	-	-	-	-	-	+	-	-	+
	Ariophantidae	*Euplecta colletti*	Endemic						+				+			
	Ariophantidae	*Euplecta layardy*	Endemic												+	
	Ariophantidae	*Euplecta sp.*			+	+	+			+		+	+			
	Ariophantidae	*Cryptozona chenui*	Endemic	+	+	-	-	-	-	-	-	-	-	-	-	-
	Ariophantidae	*Cryptozona bristralis*					+									
	Ariophantidae	*Euplecta travancorica*		+												
	Camaenidae	*Beddomea albizonatus*	Endemic			+						+	+			
	Camaenidae	*Beddomea trifasciatus*	Endemic					+								
	Glessulidae	*Glessula sinhila*	Endemic		+											
	Glessulidae	*Glessula sp.*									+		+			
	Helicarionidae	*Ratnadvipia irradians*	Endemic			+										
	Achatinidae	*Lissactina fulica*	Exotic			+										
	Subulinidae	*Subilina octana*													+	
	Endodontidae	*Philalanka sp*													+	
Prosodarnc hia	Cycloporidae	*Theobaldios bairdi*	Endemic	+		+					+					
	Cycloporidae	*Theobaldios annulatus*	Endemic						+							
	Cycloporida	*Theobaldios sp*										+				
	Cycloporidae	*Cyclophorus sp.*			+											
	Cycloporidae	*Aulophoma grande*	Endemic				+					+				
		Aulophoma sp.					+	+		+						

Plate 12

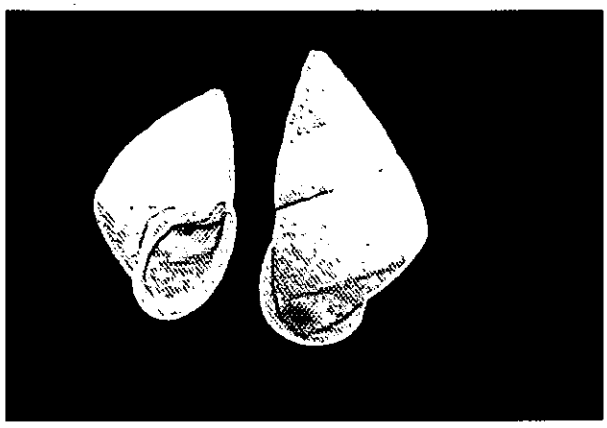


Figure 1. *Beddomea albizonatus*

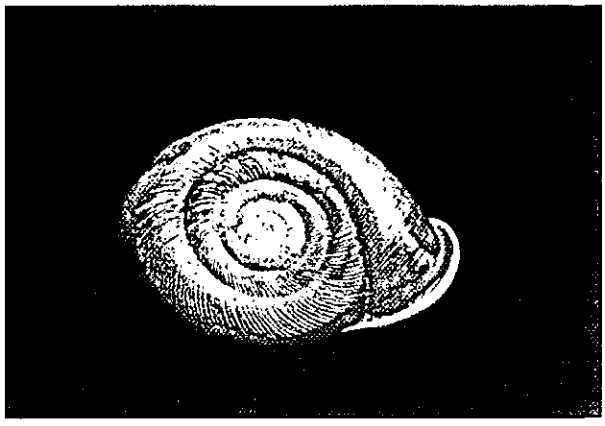


Figure 2. *Corilla erronea*

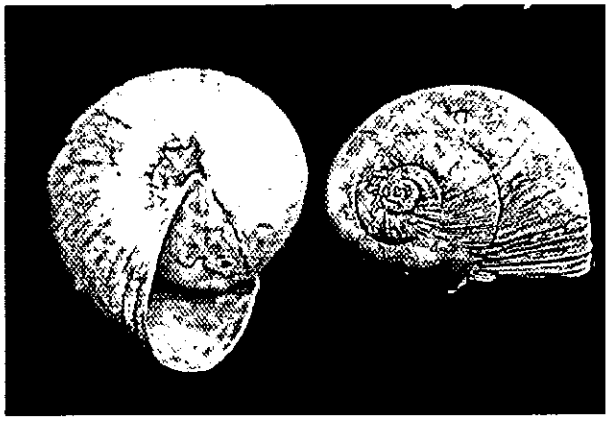


Figure 3. *Cryptozona chenui*

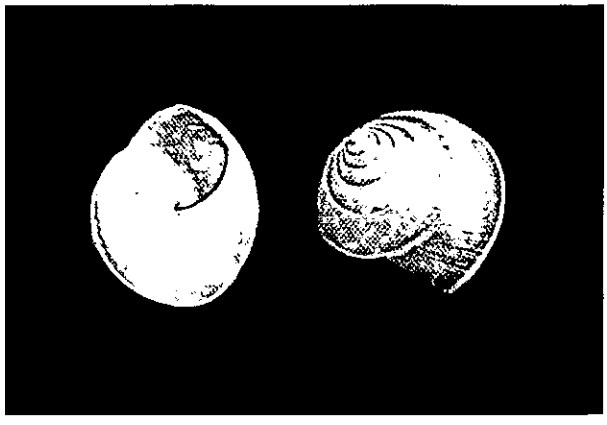


Figure 4. *Euplecta* sp.

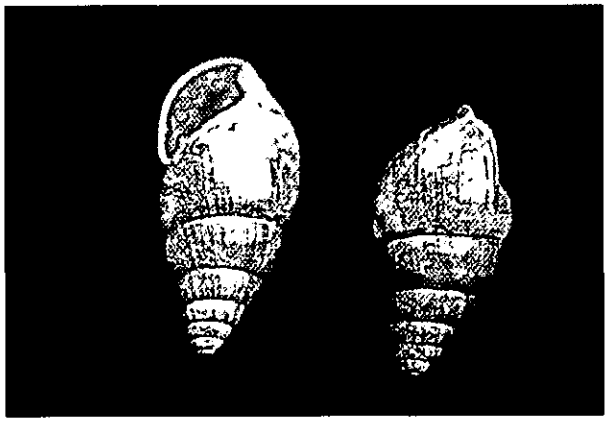


Figure 5. *Glessula* sp.

Figure 6. *Oligospira polei*

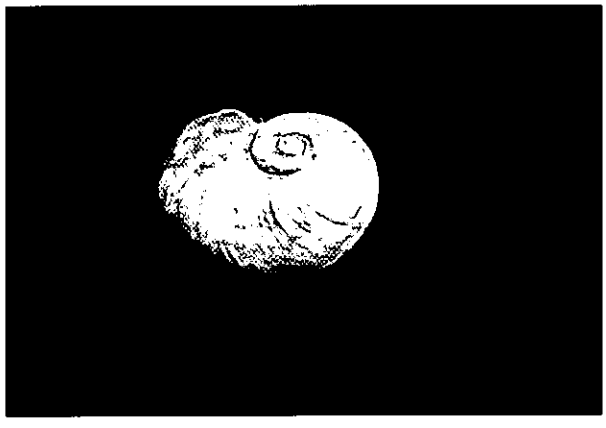


Figure 7. *Ratnadvipia irradians*

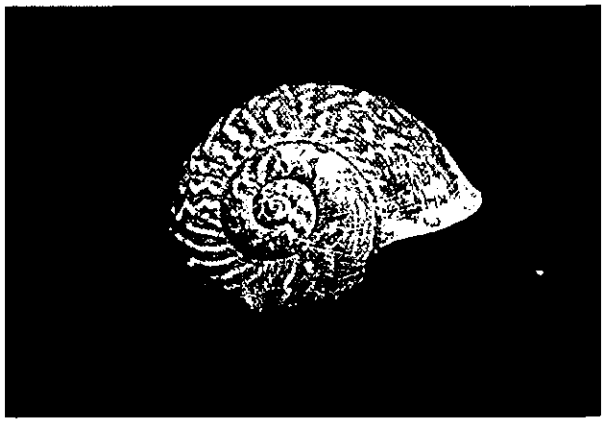


Figure 8. *Theobaldius bairdi*

Photographs: © Anslem de Silva

The Diversity of the Dumbara Mountains (The Knuckles Massif, Sri Lanka): with special reference to its herpetofauna.
Lyriocephalus Special issue, 2005 November, Volume 6 Numbers 1 & 2: 185-190
ISSN 1391–0833

EVIDENCE OF PREHISTORIC CAVE DWELLERS INHABITING THE KNUCKLES MASSIF: PRELIMINARY ARCHAEOLOGICAL FINDINGS

Anslem de Silva[1], R. M. M. Chandraratne[2], S. Goonewardene[3], W.M.R.P.K. Chandradasa[2], D. Ellepola[2] & P.B.N. Abeywardana[2]

[1]15/1 Dolosbage road, Gampola, Sri Lanka. Email: kalds@sltnet.lk
[2] Dept of Archaeology, University of Peradeniya, Sri Lanka
[3] 97, Battersea Park Road, London, SW9 4DU, UK. E-mail: hsr.wild@gmail.com (University of Edinburgh, UK)

Keywords: Mesolithic cave dwellers, Gorahadigala cave, quartz artifacts, Knuckles,

Introduction

Sites inhabited by Mesolithic cave dwellers are known from various parts of Sri Lanka (Deraniyagala, 1992, 2004). These caves are characteristic in having large accumulations of mixed ash layers and artifacts such as the remains of mammalian bones (including human), invertebrates such as mollusks and crustaceans and stone implements (Deraniyagala, 1992, 2004). During a recent survey of the Knuckles Range (June to August, 2004 and June and August 2005), several caves were discovered to have been inhabited by the Mesolithic cave dwellers.

The Knuckles or Dumbara Range is considered an important ecosystem. Geologically, a part of the Central Highland, the Knuckles is an isolated massif close to the large Dumbara and Matale valleys. A prominent feature of the Knuckles is its rugged 35 peaks which range from 915 to 1,900 m above sea level and which are covered with montane cloud forests. The Knuckles range has a highly diverse flora and fauna, some of which are peculiar to the Knuckles, thus it is categorized as a separate Floristic Region within Sri Lanka (Ashton & Gunatilleke, 1987).

The Knuckles Range has not been the subject of much extensive archaeological investigations apart from two well-known caves: Alulengala lena and the Niter Cave.These have been explored by Davy (1821); Lawrie (1898); Sarasin and Sarasin (1908); Seligmann & Seligmann (1911), Uragoda (1973) and Deraniyagala (1992). During the 2004 and 2005 Knuckles expedition by the above team, several Mesolithic caves, and significant granite carvings were found. This paper deals with artifacts observed in two of these less well-known Mesolithic caves. We propose the name Gorahadigala lena (lena = cave) for these caves.

Location and description of the Gorahadigala Mesolithic caves

The Gorahadigala is situated on the slopes of Dotulugala mountain (1575 m), Dotulugala was the first Man and Biosphere Reserve of the Knuckles Ecosystem. The caves are situated at Gorahadigala watta (7° 18' 21.6" N and 80° 50' 47.1" E), Dotulugala is close to Hunnasgiriya in the Knuckles Range, which is part of the central province and falls within the Kandy administrative districts. Two Mesolithic caves were observed at about 1000 m above sea level on a large granite rock (Plate 13 Figures 1 & 2). According to Cooray (1956), the rock in the Knuckles is from the pre-Cambrian Vijayan Complex. The main cave was situated approximately 2.5 m above the present ground level. The entrance to the cave is semicircular and measures 5 m in length and 2 m at the highest point. Inside it is 9 m long, 3 m wide (Plate 13 Figure 2). The second cave which was smaller was situated on the same rock about 5 m away. This cave was 1 m above the present ground level. The entrance to this cave was 1,75 m high and 2 m wide. Inside it was 5 m long (Plate 13 Figure 3).

Some artifacts discovered inside Gorahadigala lena (caves)

On the floor of the main cave there was a thick ash mixture covering an area of approximately 2 x 5 m and 1 meter deep. Over 1000 artifacts consisting of vertebrates (mainly mammal) bones belonging to several species of mammals and several mollusk shells and crustaceans were observed one the surface. Following are some details of the artifacts observed:

a) Middle part of the left mandible of *Moschiola meminna* (Mouse-deer); Posterior part of the left mandible of *Ratufa macroura* (Giant squirrel); Right side of the Maxilla of *Paradoxurus ceylonensis* (Sri Lanka golden palm-cat); Proximal half of the radius of *Meea chiroptera* (Mouse); Caudal vertebra, proximal end of ulna, femur head, distal part of tibia, metatarsals and metacarpals of *Trachypitecus vetulus* (leaf monkey); Caudal vertebra of *Petinomys fuscoapillus* (Small flying-squirrel) (Plate 13. Figure. 4). b) Teeth of the above mammals (Plate 13. Figure. 5).

c) Several broken pieces of *Oligospira polii* shells and hundreds of *Paladomus* species shells (Plate 13 Figure 6).

d) Stone and quartz tools (Plate 13 Figure 7).

e) Several stone implements used to smash bones too were found (Plate 13 Figure 8).

The second smaller cave had an ash mixture covering an area of approximately 1 x 2 m and 30 cm deep. Artifacts consisting of vertebrate (mainly mammal) bones belonging to several species of mammals and several mollusk shells and crustaceans were observed. In addition clear quartz implements were found on the ground below the two caves.

Discussion

The Elevation of Dotalugala is about 1000 m, where environment was suitable for Mesolithic man in Sri Lanka (Personal Communication, Siran Deraniyagala, 2005). Most quartz artifacts, which bears retouch marks, when observed through a magnifier, showed used marks. Considering other fragments like quartz, chert and stone tools suggests that they were prepared at the cave site.

A few fragments of ribs belonging to present day cattle (*Bos indicus*) indicated current activities of villagers who frequented this cave. A few rodent burrows too were observed inside the cave. A characteristic feature at Mesolithic cave sites in Sri Lanka are the predominance of bone artifacts of small mammals (Deraniyagala, 1992). Observations at Gorahadigala cave (Table 1) were similar.

Table 1
Faunal remains identified at Gorahadigala and other Mesolithic Site in Sri Lanka

Identified species	Gorahadigala Cave (present study)	Batadomba Cave**	Belilena Cave**
Tragulus meminna (Mouse Deer)	+	+	+
Ratufa macroura (Giant Squirrel)	+	+	+
Presbytis vetulus (Langur)	+	+	+
Paradoxurus zeylonensis (Civet cat)	+	+	+
Petinomys fuscocapillus (flying squirrel)	+	+	+
Paladomus sp (snail sp)	+	+	+
Lamellidens .sp (snail sp)	+	+	+
Cyclophorus sp (snail sp)	+	+	+

** Deraniyagala, S`.U. 1992. + = present

Except for Langur, the other faunal remains show the presence of more non meat bearing parts like mandible, vertebra and ribs. These are considered as food refuse. Concerning the identified fauna, some were observed during the expedition as well as in the literature (Phillips, 1980 and 1984; Arudpragasum *et al*, 1982). Snails found at Gorahadigala lena generally occur in montane streams, vegetation and rocks (Ratnapala. R. 1984; Satyamurti, 1960). A similar environment can be observed at other Mesolithic Sites like Batadeomba Cave and Belilena cave as reported by Deraniyagala (1992). Batadomba Cave has yielded *Canarium zeylanicum* and and Belilena cave has consisted of *Canarium zeylanicum as well as Artocarpus nobilis* (Table 2. Kajale, 1989, Deraniyagala, 1986 &. 1992).

Table 2
Ethno-botanical evidence from Gorahadigala and Archaeological evidence from Mesolithic sites

Plant species	Gorahadigala Cave (present study)	Batadeomba Cave *	Belilena cave. *
Canarium zeylanicum (Kekuna)	+	+	+
Artocarpus nobilis (Wild bread fruit)	+	+	+
Diascorea pentaphylla (Katu Ala)	+	-	-
Asparagus falcatus (Hatavarya)	+	-	-
Cantherium parviflorum (Karakola)	+	-	-
Mangifera zeylanica (Atamba)	+	-	-
Clausena indica (Meegon Karapincha)	+	-	-

* Deraniyagala, S.U. 1992. . + = present, - = not recorded

Several archaeological explorations indicate the importance of the central highlands as one of the nuclear areas for the prehistoric inhabitants of Sri Lanka (Wijayapala, 1998, Deraniyagala, 1992). Dating of some of the microliths, faunal, human and floral remains from Beli-lena at Kitulgala have revealed that they are from ca. 27,000 to 9000 BP (Wijayapala, 1998, Deraniyagala, 1992). However, the earliest chronology for the Mesolithic Period in Sri Lanka is from ca. 34,000 to 5400 B. P is from the Fa-Hien cave at Yatigampitiya village in Bulathsinhala (Wijayapala, 1997, Deraniyagala, 1992).

The following facts may indicate either the spread or migration of prehistoric man from the lowlands to the montane zone or *vice versa*.
The discovery of Stone Age artifacts, potsherds, bones and shells from cave sites of 'Nilgala in South-Eastern Sri Lanka (eastern lowlands of Knuckles) (Sarasin and Sarasin, 1908).

The archaeological excavations at Batadomba-lena in Kuruvita, Ratnapura which revealed a large number of animal bones, bone tools, human skeletal and floral remains along with geometric microliths (Deraniyagala, 1986; Kennedy *et al.*, 1986).
Following are some other significant archaeological findings from the central highlands:

1. The surface findings of prehistoric aspects from Peradeniya and Maskeliya by E. E. Green and J. Pole in the late 19th century (Deraniyagala, 1986).
2. The discovery of shells and mammalian bones in the Stripura cave, in the North of Vavl Kele in Kandy by Deraniyagala

(1956). At present this site is submerged under the Randenigala reservoir.

3. Findings of microliths, faunal, human and floral remains dated from ca. 27,000 to 9000 BP from the Beli-lena at Kitulgala (Wijayapala, 1998, Deraniyagala, 1992).

4. Studies on Pollen morphology at Horton Plains which shows the farming of oats and barley 10,000 BP, indicating evidence of early human occupation in the central highlands (Prematilake *et.al.*, 2001, Prematilake 2003).

5. Presence of quartz microliths and possible quarries at Horton Plains (Deraniyagala 1971, de Silva 1999).

We observed a fair number of bone artifacts of primates (*T. vetulus* = leaf monkey) in the Gorahadigala lena, suggesting that primates have been a popular item consumed. A majority of these animals may have contributed to their diet. Studies from other parts of the country have indicated that a high percentage of the animal bones were made up of western purple-faced monkey (*Trachypithecus vetulus*) and dusky toque monkey (*Macaca sinica*) (Nalinda 1990; Deraniyagala 1992). Primates are still eaten by some people in Sri Lanka. Concerning archaeological and Ethno-archaeological data, Gorahadigala cave could be regarded as a Mesolithic habitation site in Sri Lanka.

Conservation and recommendations

High rate of soil erosion at the Knuckles is known (see de Silva *et al.*, 2005 in this volume for details). It is possible that due to vast clearing of the primary forest cover at Knuckles including around Gorahadigala cave for plantations over a hundred years back has caused heavy soil erosion. At present the gradient of the ground is virtually at an angle of 60°. This could be one reason, the entrance to the main cave is 2.5 m above the present ground level. Earlier it would have been virtually flushed or slightly higher with the entrance to the cave. Thus, we recommend that some terracing is needed to prevent further soil erosion around the cave.

We observed that at Alulengala cave and the Niter Cave some illegal construction work was is in progress. Defacing the rock surface by visitors by writing their names.was also observed. Similar vandalism was observed at the cave of 'Vedda ash pictures' which contained several sketches of reptiles at Tharulengala Aranniya Senasana situated in the village of Hulannuge in Ampara District (de Silva *et al.*, 2004). Thus, it is recommended that immediate steps be taken to protect these important archaeological sites.

Acknowledgements

We thank Sarath Fernando, Conservator General, of the Forest Department. Senarath Dissanayeke, the Commissioner of Archeology, Sri Lanka, the Director General, of the Department of Wildlife Conservation. The Forest Department officers at Loolwatte and Illukkumbura for their friendly support throughout the study.

University of Edinburgh, United Kingdom for funding and supporting Project Knuckles 2004 an undergraduate research expedition (especial thanks to the following University of Edinburgh Funds: Aranmore Memorial Traveling Scholarship, Davis Fund, James Rennie Bequest, Student Travel Fund, Weir Fund, William Dickson Traveling Fund and also British Student Travel Fund, Edinburgh No 2 Fund, Gilchrist Educational Trust, Lindeth Charitable Trust, Peoples Trust for Endangered Species, Royal Geographical Society Expedition Research Grant (Gumby Award). Kelum Manamendra-Arachchi for identifying the bone artifacts.

Finally University of Edinburgh students: Polly Bramham, Alasdair Ford, Douglas Fraser, Laura Packham, and A. J. G. Burns for their support in the field.

Literature cited

Arudpragasum K. D. I. Kotalawela and S.W. Kotagama. 1982. *A Check-List of Mammals of Sri Lanka* UNESCO: Man and the Biosphere National Committee for Sri Lanka No. 9.

Ashton, M. S. & C. V. S. Gunatilleke. 1987. New light on the plant geography of Ceylon. 1- Historical plant geography. *Journal of Biogeography*, 14: 249-285.

Cooray, P. G. 1956. Geology and Structure IN: The Knuckles expedition. *Bulletin of Ceylon Geographical Society*, 10(3 & 4): 56-57.

Davy, John. 1821. *An Account of the Interior of Ceylon and of its Inhabitants with Travels in that Island*. Longman, Hurst, Rees, Orme & Brown, London, 1st Ed. (2nd Ed. (1969) Tisara Prakasakayo, Dehiwala), 282.

de Silva, Anslem. 1999. *The habitat preferences and the status of amphibians and reptiles at Horton Plains National Park.. Report*, Zoological Survey of Sri Lanka, 67 pp.

de Silva, Anslem., I. Das, A. M. Bauer & S. Goonewardene. 2004. Vedda rock art in Sri Lanka depicting reptiles with special reference to the golden gecko, *Calodactylodes illingworthorum* (Reptilia: Gekkonidae). IN: *The herpetology of Sri Lanka: current research (Including Proceedings of the Fourth World Congress of Herpetology, December 2001 and Nilgala Expedition, 2003)* Anslem de Silva (Ed): pp 213-220.

Deraniyagala, P.E.P. 1956. Some aspects of the Prehistory of Ceylon, (part V) the Balangoda Culture, *Spolia Zeylanica 28* (1): 117-20.

Deraniyagala, S.U. 1971. Archaeological exploration in Ceylon. Part I: Horton Plains. *Spolia Zeylanica*, 32 (1): 13-23.

Deraniyagala, S.U. 1986. *Prehistory of Sri Lanka; the Late Quaternary Paleo- environment;* paper presented at the World Archaeological Congress, Southampton, 1986, MS. 1-39.

Deraniyagala, S.U. 1992. *The Prehistory of Sri Lanka an ecological perspective*, Memoir Vol. 8, pt I and II, Department of Archaeology, Colombo.

Deraniyagala, S.U. 2004. *Prehistoric basis for the rise of Civilization in Sri Lanka and Southern India*, Second Vesak Commemoration Lecture-2004. Museum Theatre, Channai, Tamil Nadu. May 17, 2004.

Kajale, M.D. 1989 Mesolithic exploration of wild plants in Sri Lanka: archaeological study at the cave site of Beli-lena: *Foraging and Farming, the evolution of plant exploitation*. One World Archaeology 13. ed. (D.R. Harris and G.C. Hillman Eds.), 1989, London, Unwin Hyman.

Kennedy, K.A.R. ,T. Disotel, W.J. Roergen, T. Chiment, J.Shery. 1986. Biological anthropology of upper Pleistocene Hominid from Sri Lanka, Batadomba Lena, *Ancient Ceylon*, 6: 68-168.

Lawrie, A. C. 1898. *A gazetteer of the Central Province of Ceylon*. Volume 2. Government Printer, Colombo. Page 594.

Nalinda, Kelum. 1990. *Faunal remains from the excavations at Batadomba Lena and Kitulgala cave*, a paper presented at the National Archaeological Congress, July 3-5, Sri Lanka Foundation Institute (SLFI), Colombo

Phillips, W.W.A. 1980 (2nd Revised). *Manual of the Mammal of Ceylon*. Pt. I and II. Wild life and Nature Protection Society, Colombo.

Phillips, W.W.A. 1984. (2nd Revised) *Manual of the Mammal of Ceylon*. Pt. III. Wild life and Nature Protection Society, Colombo.

Pole, J. 1907. A few remarks on Prehistoric stones in Ceylon, Journal of Royal Asiatic Society of Ceylon. 19 (58)272-81

Premathilake, R. & S. Nilsson. 2001. Pollen morphology of endemic species of the Horton Plains National Park, Sri Lanka. *Grana*, 40: 256-279.

Prematileke, T.R. 2003. *Late Quaternary palaeoecological event stratigraphy b in the Horton Plains, central Sri Lanka*. Stockholm University: Department of Physical Geography and Quaternary Geology. Ph.D. thesis.

Ratnapala. R. 1984. Land snails: distribution and notes on ecology. In *Ecology and Biogeography in Sri Lanka*, (C.H. Fernando Ed.), pp 391-411. Dr.W.Junk Publishers,

Sarasin, P. and F. Sarasin. 1908. *Ergebnisse Naturwissens chaftlicher Forschumgen auf Ceylon. 4 die steinzeit auf Ceylon. Wiebanden*, C.W. Kreidel (In S.U. Deraniyagala 1992 The Prehistory of Sri Lanka an ecological perspective).

Satyamurti, S.T. 1960. Land and Fresh Water Molluska in the Collection of the Madras Museum. *Bulletin of Madras Government Museum*, Vol. VI No. 4. (N.S). pp. 1-174.

Seligmann, C. G. & B. Z. Seligmann. 1911. *The Veddas*. Cambridge University Press. Pp. 318-321.

Uragoda, C. G. 1973. Nitre cave and its environs. *Journal of the Royal Asiatic Society (Sri Lanka)*. 17: 37-35.

Wijayapala, W.H. 1997. *New Light on the Prehistory of Sri Lanka in the Context of Recent Investigations at cave sites*. Peradeniya, University of Peradeniya (Unpublished Ph.D. thesis)

Plate 13

Figure 1. Gorahadigala cave

Figure 2. Gorahadigala cave inside

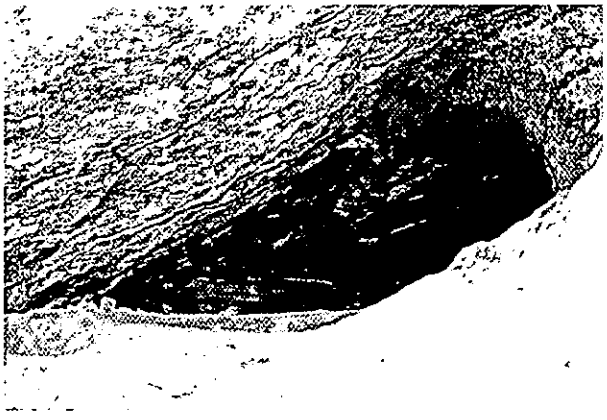


Figure 3. Second cave

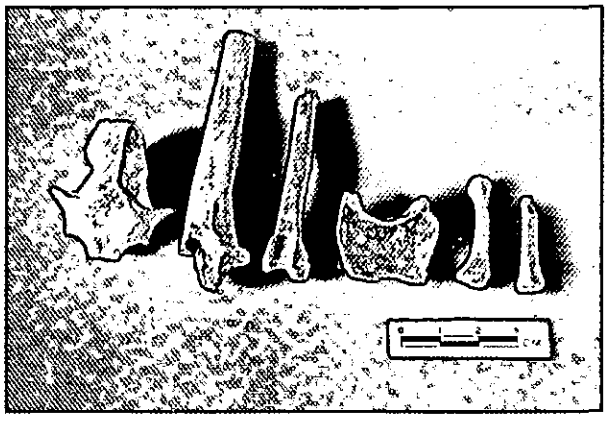


Figure 4. Mammal bone artifacts

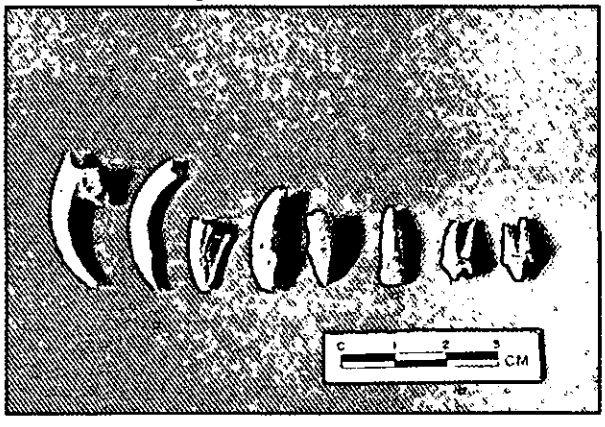


Figure 5. Mammal teeth artifacts

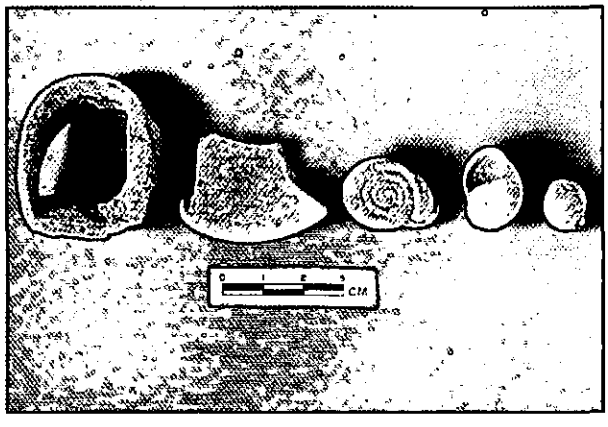


Figure 6. Mollusks

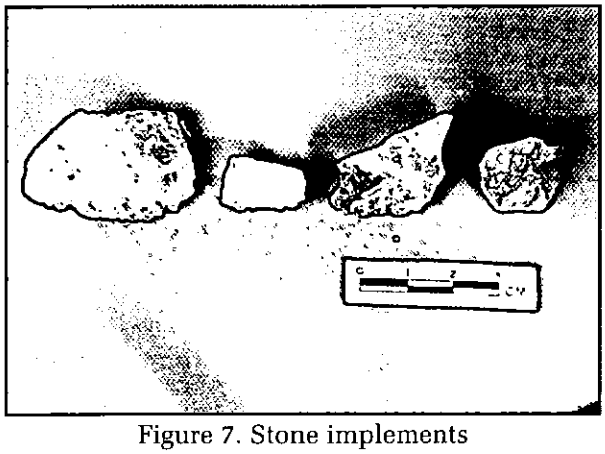


Figure 7. Stone implements

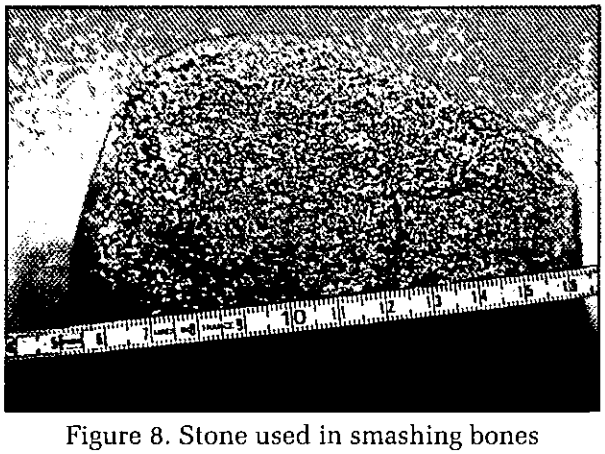


Figure 8. Stone used in smashing bones

Photographs: © Anslem de Silva

The Diversity of the Dumbara Mountains (The Knuckles Massif, Sri Lanka): With special reference to its herpetofauna.
Lyriocephalus Special issue, 2005 November, Volume 6 Numbers 1 & 2: 193-194
ISSN 1391–0833

A POSSIBLE BURIAL SITE WITH ROCK CARVINGS FROM THE KNUCKLES MASSIF

Anslem de Silva[1], Suraj Goonewardene[2] & R. M. M. Chandraratne[3]

[1]15/1 Dolosbage road, Gampola, Sri Lanka. Email: kalds@sltnet.lk
[2] 97, Battersea Park Road, London, SW9 4DU, UK. E-mail: hsr.wild@gmail.com (University of Edinburgh, UK)
[3] Dept of Archaeology, University of Peradeniya, Sri Lanka

During the first phase of the Knuckles expedition (June to August 2004) we came across an unusual set of engravings on a large granite rock (Plate 14. Figures 1 to 4) at Kobonilagala mountain, Loolwatte, located in the Knuckles approximately 1200 m above mean sea level. This particular archaeological site has not received necessary attention from the relevant authorities.

The granite slab with carvings was discovered by accident by the first author during the Knuckles Project 2004. While observing the thermoregulatory habits of the endemic agamid *Ceratophora tennentii,* fresh leopard pugmarks were observed. These pugmarks were traced to a cave which was roughly four metres long and a meter tall. The leopard, however, was not observed. To explore the inside we had to crawl through the entrance tunnel. At the end was a recently dug well approximately 2.5 m deep and 1.5 m wide. There were a number of modern clay oil lamps and plastic bags suggesting that a "*Bahirawa pooja*" (= offering ritual) had been performed in the cave at some point in the past. Traditionally treasure hunters perform a "Bahirawa pooja", thus suggesting the motive of the previous visitors to the site.

We climbed out of the cave in order to investigate its surroundings. The granite slab was partially covered with a layer of moss and ferns. On clearing a portion of moss, we observed some carvings. As we further cleared the vegetation, more engravings were revealed (Plate 14. Figures 2 to 4). The treasure hunters who had visited previously had numbered each carving using lacquer paint.

Whilst further research is required, we believe that this particular archaeological monument may be an ancient burial site, probably of a chieftain on account of its size, the intricacy of the carvings and situation on a high mountain. If this is a burial site, it could perhaps be the first of such a monument at such a high altitude.

According to Seneviratne (1984), the main burial types that can be found in Sri Lanka are: cists with capstones; pit with capstones; cairn with tumulus and urn burials. Seneviratne (1984) further reports that certain funeral sites could be identified as the megalithic burials if they contain iron artifacts and ceramic types Black and Red Ware. These are known from Peninsular India in Deccan and South India as well as Sri Lanka.

It is possible that according to Seneviratne's (1984) classification, the present burial site at Kobonilagala is a cist with capstones. In addition, the grave robbers would have removed all the "treasure" (iron artifacts, ceramic types Black and Red Ware and possibly other valuables) that would have been buried under the granite slab. This is evident by the recently dug well approximately 2.5 m deep and 1.5 m wide under the capstone slab.

Horcart (1928-33) referring to the well-known dolman at Padiyagampola in Rambukkana considers that Dolman type

burial sites is not a feature in Peninsular India.

Concerning, ethnographic evidence, villagers, who conducted certain rituals like offering food to local gods at a selected place on the mountains, urged rainfall, fertility, and prosperity as they usually do for instance in the Sri Pada, the Namunukula mountains. One of us (R. M. M. Chandratene) has observed this kind of ritual practiced in the foothills of the Namunukula mountain. However, we did not come across any evidence of this type of ritual at Kobonilagla burial site.

The following megalithic types were recorded from India.

1. Pit Circle graves: The body was first excarnated and after that interred. Grave goods are pots and Iron artifacts. A Stone circle is erected.
2. Cists: Cists are made out of granite slabs with one or more capstones that may contain single or multiple burials.
3. Laterite-cambers: Granite slabs were turned into laterite in Malabar.
4. Alignment: A large number of standing stones arranged in squares or diagonals, their height ranging from 2-6m.
5. Sarcophagi: These are legged urns of pottery.
6. Urns: Excarnated bones placed in urns and buried. They are marked by capstone or Stone circle (Agrawal, 1984, Krishnaswamy, 1949).

We feel that a well designed archaeological survey should be carried out in the Knuckles Massif to create inventories of the existing artefacts and monuments of archeological and historical interest. Relevant authorities such as the Departments of Archaeology and Forestry should initiate a conservation, management, and protection plan in order to conserve these archaeological monuments.

Acknowledgements

We thank Sarath Fernando, Conservator General, of the Forest Department and the Commissioner of Archaeology, and Mr. M. B. Herath of the Department of Archaeology, Sri Lanka.

University of Edinburgh, United Kingdom for funding and supporting Project Knuckles 2004 an undergraduate research expedition (special thanks to the following University of Edinburgh Funds: Aranmore Memorial Travelling Scholarship, Davis Fund, James Rennie Bequest, Student Travel Fund, Weir Fund, William Dickson Travelling Fund and also British Student Travel Fund, Edinburgh No 2 Fund, Gilchrist Educational Trust, Lindeth Charitable Trust, Peoples Trust for Endangered Species, Royal Geographical Society Expedition Research Grant (Gumby Award). We also wish to thank Kelum Manamendra-Arachchi for identifying the bone artifacts.

Finally University of Edinburgh students: John Drake, Polly Bramham, Alasdair Ford, Douglas Fraser, Laura Packham, and A. J. G. Burns are acknowledged for their support in the field.

Literature cited

Agrawal. D.P. 1984. Archaeology of India. Select book Syndicate. New Delhi.

Hocart. A. M. 1928-1933. Archaeology Summary. *The Ceylon Journal of Science*, Section G. Vol. II.

Krishnaswamy, 1949. Megalithic types of South India. *Ancient India* Vol. 5. pp 35-45

Seneviratne, S. 1984. The Archaeology of Megalithic Black and Red Ware Complex in Sri Lanka. *Ancient Ceylon*. pp 237-307.

Plate 14

Figure 1. Entrance to the burial chamber

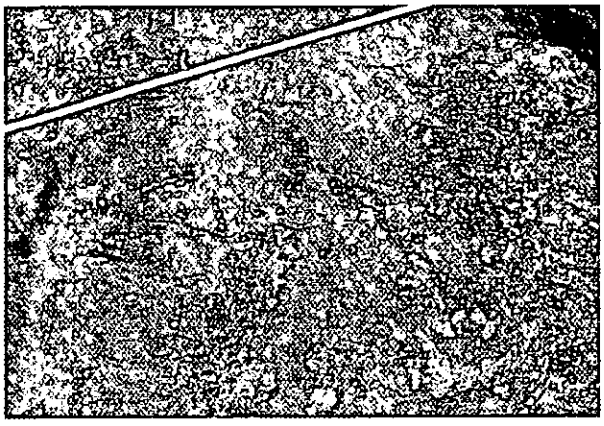


Figure 2. Carvings

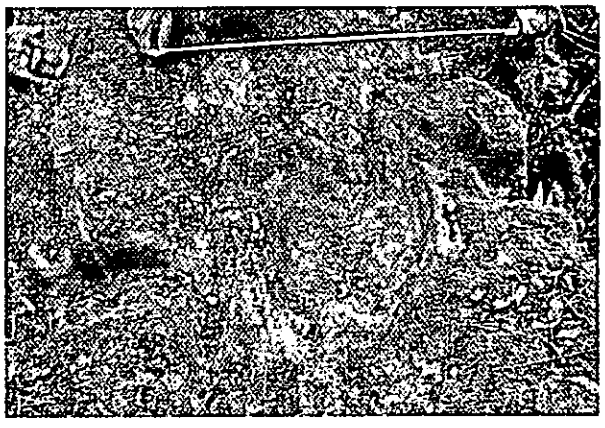


Figure 3. Carvings

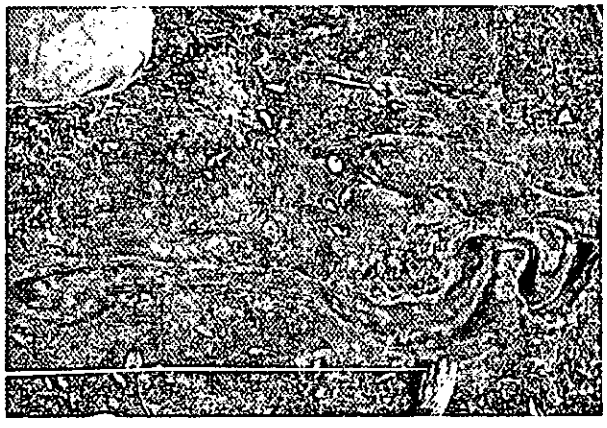


Figure 4. Carvings

Figure 5. Uyangamuwa lena

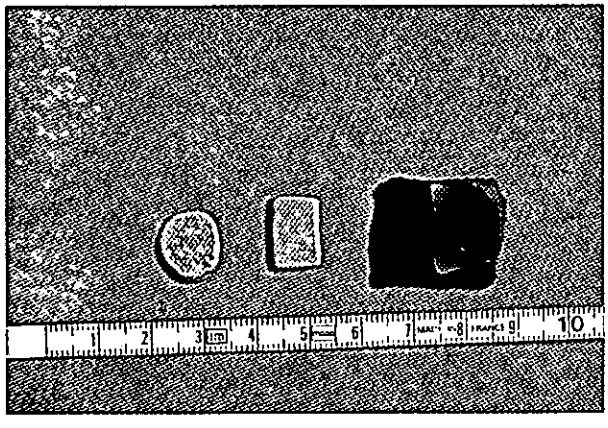


Figure 6. Chart implement & Indian silver coins

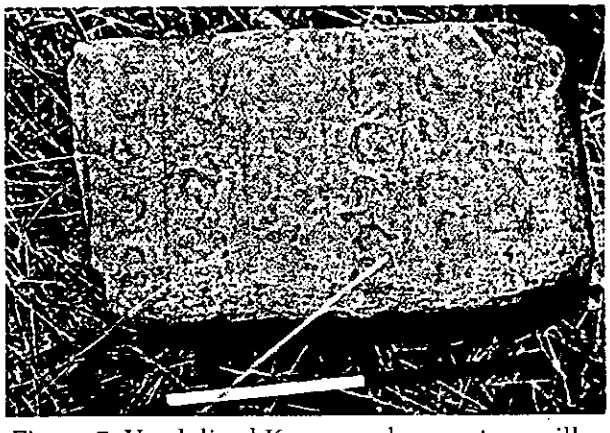


Figure 7. Vandalized Kapuruvedu oya stone pillar

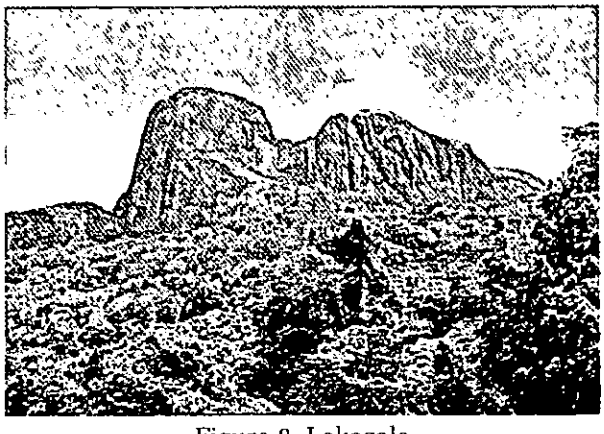


Figure 8. Lakegala

Photographs: © Suraj Goonewardene and Anslem de Silva

The Diversity of the Dumbara Mountains (The Knuckles Massif, Sri Lanka): with special reference to its herpetofauna.
Lyriocephalus Special issue, 2005 November, Volume 6 Numbers 1 & 2: 197-200
ISSN 1391–0833

SOME ARCHAEOLOGICAL MONUMENTS AND TRADITIONS OF NORTH EAST KNUCKLES

Anslem de Silva[1], R. M. M. Chandraratne[2], Suraj Goonewardene[3], J. Drake[3], J.A.D.M.M. Jayasuriya[2], P.B.N. Abeywardana[2] & W. M. R. P. K. Chandradasa[2]

[1]15/1 Dolosbage road, Gampola, Sri Lanka. Email: kalds@sltnet.lk
[2] Dept of Archaeology, University of Peradeniya, Sri Lanka
[3] University of Edinburgh, United Kingdom.

Keywords: Knuckles, archaeological monuments, traditions, folklore, caves, archaeological artifacts.

Introduction

Sri Lanka is blessed with not only a diversity of flora and fauna but also with a vast array of archaeological monuments and artefacts and a rich diversity of traditions, all of historic and prehistoric significance. Traditions are opinions, beliefs, customs and practices that are handed down from generation to generation. Though the exact vintage cannot be determined, some are several centuries old.

During two recent Knuckles Expeditions (Project Knuckles 2004 and Knuckles 2005 [Phase II]) the Knuckles were found to have their share of traditions, legends and folklore (see Samarawickram 2005 and the bibliography by de Silva 2005 in this volume). In addition, the Knuckles have many places of archaeological importance, a few of which are well known such as the Nitre cave and Alulengala cave (Davy 1821; Lawrie 1898; Sarasin and Sarasin 1908; Seligmann and Seligmann 1911; Uragoda 1973; and Deraniyagala 1992). Also during the recent Knuckles expedition, monuments of archaeological significance and several caves thought to have been inhabited by prehistoric man were observed (de Silva *et al.*,2005).

The present paper deals with some of these sites of archaeological significance as well as a selection of traditions which were observed during the Knuckles Expedition in the North East side of the Knuckles Massif.

Survey methods

Both the archaeological monuments examined in the Knuckles range and the traditional hunting methods of some residents of the region were observed whilst conducting a herpetological survey of the ecosystems of the Knuckles mountains. Information on local traditions and the location of sites of archaeological significance were collected from village elders during the Knuckles expedition.

Some archaeological monuments

Uyangamuwa lena (= cave).
Situated at 07° 23' 37.9" N 80° 50' 6.8" E (altitude 753 m). The cave is situated approximately 20 m above the ground on a huge granite rock (Plate 14. Figure 5). The entrance is approximately 2 x 2 and the depth of the cave is 6 m, height 2 meters. Present condition: We were informed that chena (slash and burn) farmers who were cultivating the flat land known as Uyangamuwa park below the cave had cleared the ash and other archaeological artefacts from the surface of the cave approximately 50 years previously so that it could be used as a watch hut. They had not realized the archaeological significance of the material contained within. On occasion, young locals continue to visit this cave. During our visit we were fortunate to observe on the ground in an obscure corner

a chart cutting / scraping tool and two Indian silver coins (Plate 14. Figure 6).

Valagamba *lena* (= cave).
According to folk tradition when King Valagambahu visited the Keselwatte area in Kikawela hamlet, he saw an ascetic monk living in a cave. The king had a drip-ledge chiselled (Piyadasa 1996) (drip ledge is an architectural feature where a groove is chiselled along the brow of the over hanging boulder at the entrance of a cave so that rain water will not come into the living quarters). The villagers call this cave Rangi ela and it is approximately 6 m tall, 10 m wide and 5 m deep. At the entrance, a drip ledge can still be seen today and the cave is currently being used by a Buddhist monk.

Nariyagala *lena*.
Nariyagala cave is situated approximately a quarter of a kilometer from Valagamba cave (on the opposite bank of Rangi ela). The cave is approximately 6 m in height, five meters wide at the entrance and has a depth of 4 m within. Again, there is a drip ledge present, suggesting that the cave has been inhabited in the past. It is possible that the drip ledge would have been carved during the same period as that of the Valagamba cave.

Kapuruvedu oya stone pillar with inscriptions (Plate 14 Figure 7).
Karunaratne (1996) has palaeographically assigned this stone pillar inscription to King Gajabahu II (1132 – 1152). The inscription on the pillar records a land grant and an *'attani'* grant for making an image as an offering in honour of the god Skanda (Karunarathne 1996). The GPS coordinates of the site are 07° 31' 14.3"N and 80° 54' 17.0 E (altitude 120 m) and the pillar is presently situated in the center of a paddy field. During Project Knuckles when we visited this site in June 2005, it was found to have been broken into pieces. Local residents informed us that vandals had broken it into pieces assuming that there was a treasure held within. Apart from the above observation it is difficult to say how many more inscriptions and caves lie hidden undiscovered. In fact, a cave at Karandaketiya (Knuckles) was observed during the last days of the expedition in September 2005. Although nothing was found here the investigation was by no means exhaustive.

Traditions
There are many legends about the folkloric King Ravana who was supposed to reign the country around the1st millennium BC. Although there is neither historical nor archaeological evidence of the existence of such a king, there are many legends woven around Ravana.

In fact, many traditional ayurvedic physicians believe in such a king and traditional literature credits medical works such as *Arkaprakasawa*, *Udisthanthrya* etc. to Ravana (Kumarasinghe 1982). There are also many villages, large granite rocks, waterfalls etc named after Ravana and Sitha such as: Ravana ella (falls); Sithagala; Sita Eliya; Yahangala; Lakegala, Diyapihilla, Yak gala (= modern Laggala), city of Lankapura, Rawana Kotte, Sita Ella (Seneviratne, 1984).

Sinhala people believe Ravana to be a man of learning, wisdom, and valour who appears to be very wicked due to his unseemly conduct in his involvement with Sita. Rawana's life is quite unknown to the people in Sri Lanka who consider him only as a prehistoric king of Sri Lanka who took away Sita from Rama. People speak of his ten heads as he was known for his learning and wisdom He has also been a great musician, known for his violin: Rawana Vina (Seneviratne, 1984). Ravana was considered a wicked demon in Northern India (Personal communication to RMMC: M. Geetha Krishnan, 1991). Further, King Kumaradasa wrote *Mahakavya* the *Janakiharana* in Sanskrit in the century AD. It gives the popular story of the abduction of Sita by Ravana at the time (Paranavitana and Godakumbure, 1967). The shrine of Upulwan at Devundara was built in the 7th Century by a king named Dappula. Paranavitana pointed out that a vast majority of people worship Upulvan and Rama at Devundara shrine. This indicates influence of Mahabharata to the Island.

It is also widely believed that Lakegala (1310 m) the most famous and spectacular mountain in the Knuckles is the site of Ravanas palace, from where he has operated his legendary *Dandumonara* (flying machine). It is also believed that Ravana used the Udathenna lena (= cave) as a resting place and observation spot to survey Maligatenna, the flat landscape stretching out below. Even today the flat land below Udathenna lena is known as Maligatenna, which means plain of the palace, strongly indicative of the former presence of the legendary monarch.

Another legend is that Hanuman, who came to Sri Lanka from India in search of Sita (who was abducted by Ravana and kept in secret at several places around Lakegala) had set up his bow and arrow at Wasgamuwa from where he shot at the palace of Ravana at Lakegala. As a result, it is believed that half of the palace fell to the land below, known today as Uyangamuwa. To date one can see that a major portion of the granite mountain has broken and fallen below (Plate 14. Figure 8). It is believed that Uyangamuwa was once Ravana's pleasure garden where he grew fruit trees and various flowering plants for aesthetic and medicinal value.

It is believed that Sita rested on a boulder (similar in shape to a large pot with a lid) on the bank of the river and that she hid her royal regalia underneath this boulder. It is also believed that prince Rama rested on the same boulder on his way from Maraka to Lakegala. When we visited the site during our survey, we observed vandalism – and that several attempts had been made to blast the stone.

The Lakegala mountain is a complex of three peaks (Plate 14. Figure 8), it is believed that the mountain in the center has two small ponds: the Sudu nika pokuna and the Kalu nika pokuna. Sudu nika or *Vitex negundo* is used widely in traditional medicine whilst Kalu nika is an imaginary plant which is said to posses the power of rejuvenating the old (Uragoda 2000) and the power to snap a gold thread if simply placed over it (de Silva, 1891).

Conservation and recommendations

Vandalism of archaeological monuments was observed at Alulengala, Nitre and Dotalugala caves (de Silva *et al.*, 2004; de Silva *et al.*, 2005). It is thus recommended that immediate steps be taken to protect these important archaeological sites. It is also recommended that traditional lore and legends be collected and recorded for posterity, before they are lost to modern culture. The inscription reported in this paper is important to understand the development of the Sinhala script as well as to understand the language of the 12th century. It is thus vital that an archaeological survey be conducted in the Knuckles Massif to locate and document any further artefacts before they are lost due to ignorance, neglect and vandalism.

Acknowledgements

We thank the Commissioner of Archeology, and Mr. M. B. Herath, Dept. of Archaeology, Sri Lanka. Mr. Sarath Fernando, Conservator General, of the Forest Department The Forest Department officers at Loolwatte and Illukkumbura for their friendly support throughout the study.

University of Edinburgh, United Kingdom for funding and supporting Project Knuckles 2004 and 2005, an undergraduate research expedition (special thanks to the following Funding Bodies: Aranmore Memorial Travelling Scholarship, Davis Fund, James Rennie Bequest, Student Travel Fund, Weir Fund, Carnegie Award, William Dickson Travelling Fund and also British Student Travel Fund, Edinburgh University No. 2 Fund, Gilchrist Educational Trust, Lindeth Charitable Trust, Peoples Trust for Endangered Species, Royal Geographical Society Expedition Research Grant (Gumby Award).

Finally we wish to thank W. Kudahena (a 93 years old villager) from Dandeniya Kumbura, Mimure who was able to recall many legends and verses pertaining to King Ravana. We also wish to thank W.P.G. Abeyawardena of Kivlewadiya, Pallegama Laggala for relating many traditions of the area.

Literature cited

Davy, J. 1821. *An Account of the Interior of Ceylon and of its Inhabitants with Travels in that Island.* Longman, Hurst, Rees, Orme & Brown, London, 1st Ed. (2nd Ed. (1969) Tisara Prakasakayo, Dehiwala), 282.

de Silva, A., I. Das, A. M. Bauer & S. Goonewardene. 2004. Vedda rock art in Sri Lanka depicting reptiles with special reference to the golden gecko, *Calodactylodes illingworthorum* (Reptilia: Gekkonidae). IN: *The herpetology of Sri Lanka: current research (Including Proceedings of the Fourth World Congress of Herpetology, December 2001 and Nilgala Expedition, 2003)* Anslem de Silva (Ed): pp 213-220.

de Silva, Anslem, R. M. M. Chandraratne, & Suraj Goonewardene. 2005. Evidence of primitive cave dwellers inhabiting the Knuckles massif: preliminary archaeological findings. *Lyriocephalus* Special issue, Volume 6 Numbers 1 & 2

De Silva, Anslem. 2005. A bibliography of publications on the Knuckles massif. *Lyriocephalus* Special issue, 2005, Volume 6 Numbers 1 & 2:

de Silva, W. A. 1891. A contribution to Sinhalese plant lore. *Journal of the Royal Asiatic Society, Ceylon Branch.* 12 (42): 113-144..

Deraniyagala, S.U. 1992. *The Prehistory of Sri Lanka an ecological perspective,* Memoir Vol. 8, pt I and II, Department of Archaeology, Colombo.

Gnanaloka, K (ed.). 1967. *Amawatura* Colombo, p 93

Karunaratne, S. 1996. Inscriptions of Matale. IN: *Historic Matale* (Ed. Board) Matale Book Publication Board. Dept. of Cultural Affairs. Colombo. pp 49-51.

Kumarasinghe, A. 1982. *Ayurveda Ithihasaya* (= History of Ayurveda). Dept. of Ayurveda. 232 pp.

Lawrie, A. C. 1898. *A gazetteer of the Central Province of Ceylon.* Volume 2. Government Printer, Colombo. Page 594.

Paranavitana, S. & C. Godakumbure. 1967. *Janakiharana*. Colombo.

Paranavitana, S. 1953. The Shrine of Upulvan at Devundara. *Memoirs of the Archaeological Survey of Ceylon* (AC vol. VI p 1 Colombo.)

Piyadasa, K. D. 1996. Folk-lore of Laggala. IN: *Historic Matale* (Ed. Board) Matale Book Publication Board. Dept. of Cultural Affairs. Colombo. pp 135-137.

Samarawickrama, H. M. G. S. 2005. An ethno-archaeological study of the inhabitants of Mimure, Knuckles. IN: *The Diversity of Dumbara Mountains (Knuckles Massif, Sri Lanka): With special reference to its herpetofauna. Lyriocephalus* Special issue, 2005, Volume 6 Numbers 1 & 2

Sarasin, P. and F. Sarasin. 1908. *Ergebnisse Naturwissens chaftlicher Forschumgen auf Ceylon. 4 die steinzeit auf Ceylon. Wiebanden,* C.W. Kreidel (In S.U. Deraniyagala 1992 The Prehistory of Sri Lanka an ecological perspective).

Seligmann, C. G. and B. Z. Seligmann. 1911. *The Veddas*. Cambridge University Press. Pp. 318-321.

Seneviratne, A. 1984. Ramayan Ravana History, Region and belief in Sri Lanka *Ancient Ceylon* No. 5: 221-236

Uragoda, C. G. 1973. Nitre cave and its environs. *Journal of the Royal Asiatic Society (Sri Lanka).* 17: 37-35.

Uragoda, G. C. 2000. *Traditions of Sri Lanka. A selection with a scientific background.* Vishva Lekha, Ratmalana. 319 pp.

The Diversity of the Dumbara Mountains (The Knuckles Massif, Sri Lanka): With special reference to its herpetofauna.
Lyriocephalus Special issue, 2005 November, Volume 6 Numbers 1 & 2: 201-206
ISSN 1391–0833

SOME CULTURAL TRAITS AND ATTITUDES OF THE INHABITANTS OF MIMURE (IN THE KNUCKLES MASSIF) TOWARDS LOCAL ANIMALS, WITH SPECIAL REFERENCE TO THE HERPETOFAUNA

Anslem de Silva[1], Aaron Bauer[2], Suraj Goonewardene[3], John Drake[3], G. S. Samarawickrama[4] & M. M. Goonasekera[5]

[1]15/1 Dolosbage road, Gampola, Sri Lanka. Email: kalds@sltnet.lk
[2]Department of Biology, Villanova University, 800 Lancaster Avenue, Villanova, Pennsylvania 19085, USA. Email: aaron.bauer@villanova.edu
[3]97, Battersea Park Road, London, SW9 4DU, UK. E-mail: hsr.wild@gmail.com (University of Edinburgh, UK)
[3]Creagard, Isle of Mull, PA75 6RA, UK. E-mail: jfdrake@gmail.com (University of Edinburgh, UK)
[4]University of Peradeniya, Sri Lanka.
[5]Dept of Biological Sciences, Rajarata University of Sri Lanka

Keywords: Knowledge of animals, attitude towards animals, poisonous plants, traditional traps, Knuckles.

Introduction

The Knuckles Massif is an important conservation forest ecosystem and a National Man and Biosphere Reserve. It is also been nominated to be an International Man and Biosphere Reserve and a Natural World Heritage Site. We believe it is important to investigate and record the traditional knowledge, beliefs and practices of its inhabitants as a part of this whole process. Traditional knowledge includes attitudes towards animals and plants as well as herbal remedies in use by local people. It is important to understand the full range of these beliefs and practices as they may vary according to the social-economic status, ethnicity, religion and the particular district within the country. Information on the knowledge, attitudes and practices of the inhabitants towards the fauna and flora should be an integral part of conservation and management strategies in this region. Local people interact closely with the various Knuckles ecosystems and thus have a direct impact upon it. Without their help, support, and local knowledge conservation plans will be less effective in the long term.

Amphibians and reptiles play a significant role in the culture of Sri Lanka. Beliefs about them continue to influence the daily lives of many people. These beliefs include, for example: that cobras take revenge; that the vocalizations, defecation and other behaviours of geckos presage either good or misfortune.

During a recent field programme investigating the herpetofauna of the Knuckles Massif, a day was set aside to investigate the "knowledge, attitudes and practices" of locals towards the fauna and flora (especially reptiles). Both students and local people from the ancient village of Mimure were interviewed.

Methodology

On 17th July 2004, a structured questionnaire was handed out to 21 (nine to fifteen year old) school children randomly selected from a school in Mimure. Children were also selected from a different school at Kaikawela (a kilometer away from Mimure). Six adults from Mimure village were also interviewed.

Results

The responses of the students and adults are given in Tables 1 to 11. The totals of

some tables may not add up to the total number of students (21) and adults (6) as some students did not answer all the questions.

Discussion and recommendations

Mimure is an ancient isolated village in the Knuckles, it has been cut off from the rest of civilization until recently. John Davy (1790-1868), a British doctor, graduate of medicine at Edinburgh University, reported an interesting account of his visit to the Nitre cave in 1819. Davy also records his visit to the "secluded village of Mimure" (Davy, 1821). Archibald Lawrie (District Judge of Kandy from 1873 to 1892) in his monumental work "Gazetteer of the central province of Ceylon" reports that a population of 169 inhabitants were living in Mimure in 1878 (Lawrie, 1898). Thus, it was felt that developing an understanding of the knowledge, attitudes and practices of the inhabitants of an isolated village would be of general interest. Also, as our main research was mainly concerned with reptiles and amphibians of the Knuckles forest, we included a number of questions about reptiles in the questionnaire.

The educational level and age range of the respondents are given in Tables 1 and 2. From our questions we discovered that only four students from Mimure have seen the Dumbara bent toed gecko (*Cyrtodactylus soba*), whereas all of the adults had seen it (Table 4). This was different to our observations at Nilgala, where, of the 81 students questioned, 60 had observed the dominant gecko of the Nilgala forest - the golden gecko: *Calodactylodes illingworthorum* (de Silva *et. al.*, 2004a). This result may be due to the fact that the Dumbara bent toed gecko (*Cyrtodactylus soba*), is more confined to the montane areas than the golden gecko, hides during the day (whereas the golden gecko is diurnal???) and is less vocal than the golden gecko.

Of the eight species of animals listed in the questionnaire (Table 5), the students and adults (96%) considered the cat as the main predator of geckos at Knuckles. This was followed by snakes (48%) and ants (41%). During the survey we observed several species of snake that feed on geckos (mainly *Boiga* and *Lycodon* species) as well as an incident of ants feeding on uropeltids and a caecilian (*Ichthyophis glutinosus*). However, whether this was a dead snake or had been killed by ants was not clear. Although many species of amphibians inhabit Knuckles, all respondents considered that they had not observed amphibians feeding on geckos. Three in the present study had observed agamids feeding on geckos (Table 5).

In a previous study at Nilgala, cats also ranked high (55%) as a predator of geckos, followed by snakes (28%) (de Silva *et. al.*, 2004a). However, at Nilgala ten students had observed amphibians feeding on geckos. During field investigations at Nilgala we observed an *Otocryptis wiegmanni* (Sri Lankan kangaroo lizard) feeding on a gecko (de Silva *et. al.*, 2004b).

In the present study, 16 people (59%) reported that they had seen more than seven species of snakes (Table 6). 96% of those taking part in the present study at Knuckles had killed snakes. This high proportion may be the result of people not being able to distinguish venomous from non venomous snakes. Alternatively, it could also be the result of the high incidence of snakebite amongst inhabitants. 63% of respondents stated that at least one of their family members had been bitten by a snake.

Students had also observed other reptile species in the Knuckles (Table 7). Amongst these were the star tortoise (*Geochelone elegans*) and the Flap-shell terrapin (*Lissemys punctata*).

The transmission beliefs about reptiles from parents to offspring is very strong in Sri Lanka, especially the belief that lizards are poisonous. In the present study 63 to 67% of the respondents believed that geckos and skinks were poisonous (Table 8). The majority of people in Sri Lanka believe *Varanus salvator* to be poisonous. At Knuckles a high percentage (89%) of respondents (including all the adults) believed that the water monitor (*Varanus*

salvator) was poisonous, whereas the land monitor (*Varanus bengalensis*), which is eaten by people in many areas of the country, was not considered so.

Although a high percentage of respondents considered that geckos and skinks were poisonous (Table 8), only a few (4 to 11%) had killed them (Table 9). At Nilgala, however, 14 to 19 % of people had killed these animals (de Silva *et. al.*, 2004a). A high percentage of mammals (89%) and birds (78%) were also killed. This was mainly for consumption and for sale. We also observed several ingenious traditional animal traps set out in several locations in the Knuckles forest as well as dead mammals.

The respondents listed ten species of plants as being poisonous in total. Of these, six were listed by many people as poisonous (Table 10). Kahambiliya (*Fleurya interrupta*) was considered poisonous by all respondents. However, Kahambiliya (*Fleurya interrupta*) is only a skin irritant and not as highly poisonous a plant as Kanneru (*Nerium oleander*), which is a well known poisonous plant which is commonly used to commit suicide. In Knuckles 81% of the respondents listed Niyangala (*Gloriosa superba*) as poisonous. There are several medical reports from Sri Lanka of human poisoning due to ingestion of Niyangala (*Gloriosa superba*).

It is a common practice in rural areas in Sri Lanka to crush the leaves of certain medicinal plants and apply the juice and crushed pulp to minor cuts and bruises. The plants used in the Knuckles area are listed in Table 11. 96% of the respondents reported that they use Kikirindiya (*Coix lacryma-jobi*) for minor cuts and bruises.

In order to raise awareness, we informed all of the students that agamids, geckos and skinks were not poisonous. We also told them of the importance of these reptiles as additions to the biodiversity of the area and as insect predators. A coloured sticker depicting *Ceratophora tennentii* and *Cyrtodactylus soba* (Plate 5. Figures 5 & 6) was presented to those who took part in the survey as well as to the householders around Mimure. It is local people who can most effectively contribute to the future of conservation and management of the high diversity of the Knuckles forest as opposed to government officers of the Department of Forest and Wildlife Conservation.

Acknowledgements

We thank the Head Master of Mimure School and the students and villagers of Mimure for their cooperation in responding to the questionnaire. Global Gecko Association (John Rudge) sponsored the stickers.

We wish to thank: Mr. Sarath Fernando, Conservator General, Forest Department for permission granted to (AdS, AB and CA) (FRC/5 and FRC/6) to conduct the above study. Director General, Department of Wildlife Conservation for approvals. The Forest Department officers at Loolwatte and Illukkumbura for their friendly support throughout the study.

University of Edinburgh, UK for funding and supporting project knuckles 2004 undergraduate research expedition (special thanks to the following University of Edinburgh Funds: Aranmore Memorial Traveling Scholarship, Davis Fund, James Rennie Bequest, Student Travel Fund, Weir Fund, William Dickson Traveling Fund and also British Student Travel Fund, Edinburgh No 2 Fund, Gilchrist Educational Trust, Lindeth Charitable Trust, Peoples Trust for Endangered Species, Royal Geographical Society Expedition Research Grant (Gumby Award).

Finally University of Edinburgh students: Polly Bramham, Alasdair Ford, Douglas Fraser, Laura Packham, and A. J. G. Burns for their support in the field.

Aaron Bauer was supported by funds from the Department of Biology at Villanova University.

Literature cited

Davy, John. 1821. An Account of the Interior of Ceylon and of its Inhabitants with Travels in that Island. Longman,

Hurst, Rees, Orme & Brown, London, 1st Ed. (2nd Ed. (1969) Tissara Prakasakayo, Dehiwala), 282 p.

de Silva, Anslem, A. Bauer, C. Austin, B. J. K. Perera, R. L. Jayaratne, M. M. Goonasekera, S. Goonawardena, Z. Hawke, V. Vanneck, & A. Drion. 2004a. Some cultural traits of the inhabitants of the Nilgala fire savannah, Sri Lanka towards animals with special reference to the herpetofauna. IN: The Herpetology of Sri Lanka: current research (Including the Proceedings of the Fourth World Congress of Herpetology, December 2001 and Nilgala Expedition Report, 2003). Lyriocephalus special edition. 2004 Volume 5 (1 & 2): 183-191.

de Silva, Anslem, A. Bauer, A. Drion, . A. Fabry, S. Goonawardena, Z. Hawke & V. Vanneck. 2004b. A gecko predator at Nilgala Fire Savannah, Sri Lanka. Gekko, 4(1): 15-17.

Lawrie, A. C. 1898. A gazetteer of the Central Province of Ceylon. Volume 2. Government Printer, Colombo. Page 594.

Table 1
Age structure of the students from Mimure and Kaikawela Schools: 2004

Age	Total students (percent)	Total adults (percent)
9 to 10	7 (35%)	-
11 to 12	5 (25%)	-
13 to 14	6 (30%)	-
15	2 (10%)	-
20 to 67	-	6

Table 2
Distribution of the grade of the students: 2004

Grade	Students	Adults
4	2	1
5	5	-
6	2	-
7	2	-
8	7	2
9	1	-
10	1	-
11	1	3

Table 3
Number of gecko species observed: 2004

No of species	Students	Adults	Total
1 species	7	-	7
2 species	9	4	13
3 species	3	3	6
> 4 species	3	-	3

Table 4
Frequency of Dumbara bent toed geckos observed: 2004

No of sighting	Students	Adults	Total
1 to 3	2	2	4(19%)
4 to 6	1	1	2(7%)
Over 20	01	05	6 (22%)
Not seen	18	2	20 (74%)

Table 5
Gecko Predators observed: 2004

Animal species	Students	Adults	Total (percent)
Frogs	-	-	-
Snakes	9	4	13(48%)
Monitor lizard	-	1	1(4%)
Agamid lizards	1	2	3(11%)
Birds	2	3	5(19%)
Cats	21	5	26(96%)
Dogs	-	-	-
Ants	10	1	11(41%)

Table 6
Instances of snake species observed and attitudes towards snakes and the incidence of snakebite: 2004

No of species	Students	Adults	Total
1–3 species	-	-	-
4-6 species	11	-	-
7 > species	10	6	16(59%)
Snakes Killed	20	6	26(96%)
Snake bite in family	13	4	17(63%)

Table 7
Number of reptile species observed: 2004

Reptile group observed	Students	Adults	Total
Star tortoise	4	6	10(37%)
Flap-shell terrapin	2	6	8(30%)
Water monitor	19	6	25(93%)
Land monitor	20	6	26(96%)
Geckos	21	6	27(100%)
Skinks	21	6	27(100%)
Agamids	21	6	27(100%)

Table 8
Reptiles and amphibians considered poisonous: 2004

Reptile group	Students	Adults	Total
Frogs	1	-	1
Star tortoise	2	4	6(22%)
Flap-shell terrapin	-	-	-
Water monitor	18	6	24(89%)
Land monitor	-	-	-
Geckos	16	2	18(67%)
Skinks	14	3	17(63%)
Agamids	4	1	5(19%)

Table 9
Animals killed: 2004

Animal	Students	Adults	Total (percent)
Geckos	3	-	3(11%)
Skinks	1	-	1(4%)
Tortoises	4	4	8(30%)
Land Monitors	5	6	11(41%)
Birds	17	4	21(78%)
Mammals	18	6	24(89%)

Table 10
Plants listed as poisonous by the respondents: 2004

Poisonous plants	Students	Adults	Total (%)
Daluk (*Euphorbia antiquorum*)	10	6	16(59%)
Wara (*Calotropis gigantean*)	16	3	19(70%)
Niyangala (*Gloriosa superba*)	17	5	22(81%)
Kanneru (*Nerium oleander*)	14	2	16(59%)
Kahambiliya (*Fleurya interrupta*)	21	6	27(100%)
Mausa (*Laportea creunlata*)	19	6	25(93%)

Table 11
Plants used for minor cuts and abrasions by the respondents: 2004

Plants used	Students	Adults	Total (%)
Patas (*Ajeratu conyzoydes*)	-	-	-
Kikirindiya (*Coix lacryma-jobi*)	21	5	26(96%)
Kadupahara (*Emilia sonchifolia*)	2	5	7(26%)
Hulanthala (*Ageratum conyzoides*)	15	4	19(70%)

The Diversity of the Dumbara Mountains (The Knuckles Massif, Sri Lanka): With special reference to its herpetofauna.
Lyriocephalus Special issue, 2005 November, Volume 6 Numbers 1 & 2: 207-213
ISSN 1391–0833

SOME GEOLOGICAL ASPECTS OF THE KNUCKLES MASSIF

S.N. Wickramaratne [1] & W.M.G.B. Giragama[2]

[1]*Dept of Geography, University of Peradeniya, Sri Lanka. Email: snimalw@hotmail.com*
[2] *H.K. Agrarian Research and Training Institute, Colombo, Sri Lanka*
gbgiragama@yahoo.com

Keywords: Knuckles, geology, physiography,. Lithology, mineralogy, soil.

Introduction

The Knuckles Massif, the northern part of the hill country of Sri Lanka is lithologically similar to the main part of the central mountains. Its topographic diversity, climatic and hydrological importance as well as its ecological uniqueness has been understood.

The Knuckles Massif (locally known as the *Dumbara Kanduwetiya*) is the northern block of the hill country of Sri Lanka. It is separated from the central highlands in the south by the Kandy Plateau and on its southwestern, southern and eastern margins by the "Dumbara Valley' (i.e. Dumbara Synform) of the River Mahaweli. The Hunnasigiriya-Medamahanuwara Pass (gap) – through which the Kandy-Mahiyangana A26 road runs - separates the Hunnasgiriya Hill from the main ridge. However, strictly speaking, the southern boundary of the range can be considered as extending to include such hills as Lunukiri Kanda, Migonmana and Weddandamana. The latter is the left bank hill of the Randenigala Dam built across the Mahaweli. Northward the range extends as far as Amban Ganga Valley, only separated by the Bata Danduwa Pass which accommodates the Rattota-Pallegama road. Its western margin is demarcated by the Matale Valley. The entire Knuckles area is geomorphologically irregular and, complex both physiographically and structurally. The approximate geographic coordinates of the Knuckles area are: $7^0$18' and $7^0$35' N and $80^0$41' and $80^0$55' E. It is considered a part of the 'Upper Mahaweli Watershed'.

Method of Study

The present study was conducted during the years 1990-1994. It was primarily based on field investigations. Field work was carried out to cover the following parts of the range: Loolwatte-Attalamettuwa (Corbet's Gap) area including the stretch of the Deenston Trail, Northern parts including Ensalwatte-Riverston-Kirimeti Kanda stretch, Meemure-Ranamure to Bambarella via Tennewadiya and Kalupahana. Some of the specific locations studied were; Corbet;s Gap, Mimure, Narangamuwa, Pallegama, Bambarella, Dotalugala, Kirimetikanda Tangappuwa and Selvakanda and the Knuckles Peak (Fig.1).

Main survey techniques used were observations and field measurements by the use of clinometers and Brunton compasses. An altimeter was used to determine heights. Rock samples were collected and identified and soil hardness was measured using the penetrometer.

The field map used was the "Land use map of Knuckles Conservation area" compiled by Natural Resources Management Services, Polgolla (2004). Also 1: 50,000 maps published (2002) by the Survey Department (Sheet Nos. 48,49,54,55)

published in 1989) and Geological Survey Sheet No 49 (1: 63, 360) were used.

Much information was gathered from published works (e.g. Cooray (1956) de Rosayro (1958), Vithanage (1970), Dimantha (1988).

Results and Discussion

General physiography.

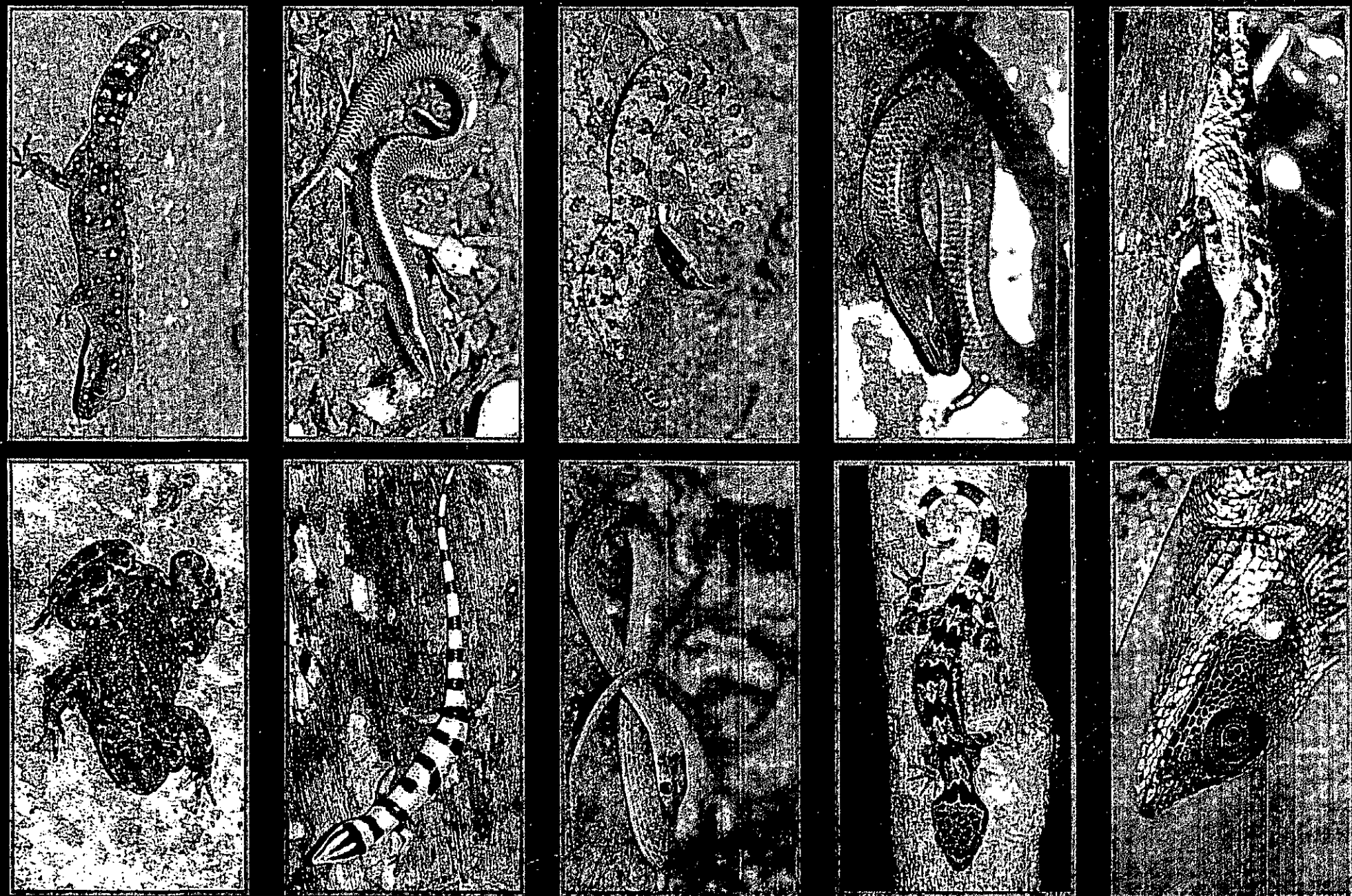
Physiographically, adjoining the Kandy Plateau, the Knuckles Massif forms a range of hills extending over a 20km distance, with a NW-SE orientation and covers some 150km^2. Rising from about 600m on its western slopes the range shows a sharp drop to the lowland plains (100m) of the dry zone on the east. This explains why Ratne Ella, the principal water fall of the area is found on the eastern slope of the range.

Early British planters named the Dumbara Hills as the 'Knuckles Range' as the five prominent peaks there when viewed from a distance resemble the knuckles of a man. There are a number of high peaks along the main ridge of the Dumbara Hills namely; (north to south) Pathanagala (1514m), Ratmetiya (1472m), Kirigalpotta (1647m), Gombaniya (1904m) the highest, Knuckles (1863m), Kobonillagala (1554m) Dotolugala (1574m) and Nawanagala (1486m). There are three more or less parallel extensions of the range that appear nearly perpendicular to the main ridge; Dumbanagala-Kehelpothdoruwegala, Kalupahana-Labulesssapatana and Lakegala and Lahumanagala-Rambukkoluwa. The elevations of the peaks of these extension are as follows: Dumbanagala (1641m), Kehelpothdoruwegala (1529m),. Kalupahana (1628m), Labullessapatana (1222m), Lakegala (1318m), Lahumanagala (1100m) and Rambukkoluwa (1113m).These ridges extending in a SW-NE direction separate the drainage systems of the streams; Hasalaka Oya, Heenganga, Kaluganga and Teligam Oya. Another lower ridge showing a NNW-SSE orientation straddles from about Rattota close to Wattegama via Madulkele, west of the main ridge forming the Huluganga valley (i.e. Huluganga Synform), in which the stream flows southward to join the Mahaweli Ganga. Among the other conspicuous peaks of the Knuckles area are Dumbanagala(1641m),Wamarapugala (1558m), Telambugala (1331m), Velangala (1180m) and Galtuna (1145m). There is also a number of subordinate peaks in the Knuckles complex; Kehelpatana, Kinihirigala, Kobeyihela, Patanagala and Rilagala northward, Kehelpathgala, Weliketiye Kanda, Yahangala, Telambugala, Umbugala and Batadandu Kanda in the east, Marthuwegala, Gerandigala, Kurulugala and Belungala in the mid southeast and, Hunnasgiriya, Galpadihela, Welikandahena, Nagollahena, Galhiriyakanda and Kodibendahela in the south as left bank hills of the Dumbara Valley. Most of these hills, especially those in the east such as Lakegala and Yahangala are monadnocks.

The altitudinal range of the Knuckles appears to be between 100 and 1904m above Mean Sea Level (AMSL). "The Knuckles group has more markedly the characteristic features of the hill country of Ceylon" (de Rosayro 1958). According to Vithanage (1970) this area comes within the *uplands* comprising of ridges, valleys, highly dissected plateaux and arenas.

An analysis of topographical maps covering the Dumbara Hills shows that most streams originating in the Dumbara Hills tend to have natural break points in their long profiles around the elevations of 750-800m and 1000-1110m (Madduma Bandara 1991). The natural break points in the stream profiles may indicate certain thresholds in the elevation ranges, which are significant topographically, hydrologically and ecologically. Based on field measurements Wickramaratne (1991) has shown that the threshold of break of slopes is 1050m, especially on the western slopes).

Cooray (1998) recognized three principal physiographic units of the Knuckles Region; (Figure 2) Knuckles Massif, Central Parallel Ridges (mentioned above) and Western Slopes along with four drainage basins namely (north to south) Kaluganga Basin, Mimure Basin, Kalaugala Basin (i.e.



DESIGNED & PRINTED BY [illegible] (CREATIVE), KANDY, SRI LANKA. TEL: +94 81 4472048 Cover design by: Anuja Mike Fernando tonija@sltnet.lk