

Building evidence for conservation globally

Journal of Threatened TAXA



Open Access

10.11609/jott.2023.15.9.23827-23930

www.threatenedtaxa.org

26 September 2023 (Online & Print)

15(9): 23827-23930

ISSN 0974-7907 (Online)

ISSN 0974-7893 (Print)





Publisher

Wildlife Information Liaison Development Societywww.wild.zooreach.org

Host

Zoo Outreach Organizationwww.zooreach.org43/2 Varadarajulu Nagar, 5th Street West, Ganapathy, Coimbatore, Tamil Nadu 641006, India

Registered Office: 3A2 Varadarajulu Nagar, FCI Road, Ganapathy, Coimbatore, Tamil Nadu 641006, India

Ph: +91 9385339863 | www.threatenedtaxa.orgEmail: sanjay@threatenedtaxa.org

EDITORS

Founder & Chief Editor

Dr. Sanjay MolurWildlife Information Liaison Development (WILD) Society & Zoo Outreach Organization (ZOO),
43/2 Varadarajulu Nagar, 5th Street West, Ganapathy, Coimbatore, Tamil Nadu 641006, India

Deputy Chief Editor

Dr. Neelesh Dahanukar

Noida, Uttar Pradesh, India

Managing Editor

Mr. B. Ravichandran, WILD/ZOO, Coimbatore, Tamil Nadu 641006, India

Associate Editors

Dr. Mandar Paingankar, Government Science College Gadchiroli, Maharashtra 442605, India**Dr. Ulrike Streicher**, Wildlife Veterinarian, Eugene, Oregon, USA**Ms. Priyanka Iyer**, ZOO/WILD, Coimbatore, Tamil Nadu 641006, India**Dr. B.A. Daniel**, ZOO/WILD, Coimbatore, Tamil Nadu 641006, India

Editorial Board

Dr. Russel Mittermeier

Executive Vice Chair, Conservation International, Arlington, Virginia 22202, USA

Prof. Mewa Singh Ph.D., FASc, FNA, FNAsc, FNAPsyRamanna Fellow and Life-Long Distinguished Professor, Biopsychology Laboratory, and
Institute of Excellence, University of Mysore, Mysuru, Karnataka 570006, India; Honorary
Professor, Jawaharlal Nehru Centre for Advanced Scientific Research, Bangalore; and Adjunct
Professor, National Institute of Advanced Studies, Bangalore**Stephen D. Nash**Scientific Illustrator, Conservation International, Dept. of Anatomical Sciences, Health Sciences
Center, T-8, Room 045, Stony Brook University, Stony Brook, NY 11794-8081, USA**Dr. Fred Pluthero**

Toronto, Canada

Dr. Priya Davidar

Sigur Nature Trust, Chadapatti, Mavinahalli PO, Nilgiris, Tamil Nadu 643223, India

Dr. Martin FisherSenior Associate Professor, Battcock Centre for Experimental Astrophysics, Cavendish
Laboratory, JJ Thomson Avenue, Cambridge CB3 0HE, UK**Dr. John Fellowes**Honorary Assistant Professor, The Kadoorie Institute, 8/F, T.T. Tsui Building, The University of
Hong Kong, Pokfulam Road, Hong Kong**Prof. Dr. Mirco Solé**Universidade Estadual de Santa Cruz, Departamento de Ciências Biológicas, Vice-coordenador
do Programa de Pós-Graduação em Zoologia, Rodovia Ilhéus/Itabuna, Km 16 (45662-000)
Salobrinho, Ilhéus - Bahia - Brasil**Dr. Rajeev Raghavan**

Professor of Taxonomy, Kerala University of Fisheries & Ocean Studies, Kochi, Kerala, India

English Editors**Mrs. Mira Bhojwani**, Pune, India**Dr. Fred Pluthero**, Toronto, Canada**Mr. P. Ilangovan**, Chennai, India**Ms. Sindhura Stothra Bhashyam**, Hyderabad, India**Web Development****Mrs. Latha G. Ravikumar**, ZOO/WILD, Coimbatore, India**Typesetting****Mrs. Radhika**, ZOO, Coimbatore, India**Mrs. Geetha**, ZOO, Coimbatore India**Fundraising/Communications****Mrs. Payal B. Molur**, Coimbatore, India**Subject Editors 2020–2022****Fungi****Dr. B. Shivaraju**, Bengaluru, Karnataka, India**Dr. R.K. Verma**, Tropical Forest Research Institute, Jabalpur, India**Dr. Vatsavaya S. Raju**, Kakatiya University, Warangal, Andhra Pradesh, India**Dr. M. Krishnappa**, Jnana Sahyadri, Kuvenpu University, Shimoga, Karnataka, India**Dr. K.R. Sridhar**, Mangalore University, Mangalagangotri, Mangalore, Karnataka, India**Dr. Gunjan Biswas**, Vidyasagar University, Midnapore, West Bengal, India**Dr. Kiran Ramchandra Ranadive**, Annasaheb Magar Mahavidyalaya, Maharashtra, India**Plants****Dr. G.P. Sinha**, Botanical Survey of India, Allahabad, India**Dr. N.P. Balakrishnan**, Ret. Joint Director, BSI, Coimbatore, India**Dr. Shonil Bhagwat**, Open University and University of Oxford, UK**Prof. D.J. Bhat**, Retd. Professor, Goa University, Goa, India**Dr. Ferdinand Boero**, Università del Salento, Lecce, Italy**Dr. Dale R. Calder**, Royal Ontario Museum, Toronto, Ontario, Canada**Dr. Cleofas Cervancia**, Univ. of Philippines Los Baños College Laguna, Philippines**Dr. F.B. Vincent Florens**, University of Mauritius, Mauritius**Dr. Merlin Franco**, Curtin University, Malaysia**Dr. V. Irudayaraj**, St. Xavier's College, Palayamkottai, Tamil Nadu, India**Dr. B.S. Kholia**, Botanical Survey of India, Gangtok, Sikkim, India**Dr. Pankaj Kumar**, Department of Plant and Soil Science, Texas Tech University, Lubbock, Texas, USA.**Dr. V. Sampath Kumar**, Botanical Survey of India, Howrah, West Bengal, India**Dr. A.J. Solomon Raju**, Andhra University, Visakhapatnam, India**Dr. Vijayasankar Raman**, University of Mississippi, USA**Dr. B. Ravi Prasad Rao**, Sri Krishnadevaraya University, Anantapur, India**Dr. K. Ravikumar**, FRLHT, Bengaluru, Karnataka, India**Dr. Aparna Watve**, Pune, Maharashtra, India**Dr. Qiang Liu**, Xishuangbanna Tropical Botanical Garden, Yunnan, China**Dr. Noor Azhar Mohamed Shazili**, Universiti Malaysia Terengganu, Kuala Terengganu, Malaysia**Dr. M.K. Vasudeva Rao**, Shiv Ranjan Housing Society, Pune, Maharashtra, India**Prof. A.J. Solomon Raju**, Andhra University, Visakhapatnam, India**Dr. Mander Datar**, Agharkar Research Institute, Pune, Maharashtra, India**Dr. M.K. Janarthanam**, Goa University, Goa, India**Dr. K. Karthigeyan**, Botanical Survey of India, India**Dr. Errol Vela**, University of Montpellier, Montpellier, France**Dr. P. Lakshminarasiham**, Botanical Survey of India, Howrah, India**Dr. Larry R. Noblick**, Montgomery Botanical Center, Miami, USA**Dr. K. Haridasan**, Pallavur, Palakkad District, Kerala, India**Dr. Analinda Manila-Fajard**, University of the Philippines Los Baños, Laguna, Philippines**Dr. P.A. Siru**, Central University of Kerala, Kasaragod, Kerala, India**Dr. Afroz Alam**, Banasthali Vidyapith (accredited A grade by NAAC), Rajasthan, India**Dr. K.P. Rajesh**, Zamorin's Guruvayurappan College, GA College PO, Kozhikode, Kerala, India**Dr. David E. Boufford**, Harvard University Herbaria, Cambridge, MA 02138-2020, USA**Dr. Ritesh Kumar Choudhary**, Agharkar Research Institute, Pune, Maharashtra, India**Dr. A.G. Pandurangan**, Thiruvananthapuram, Kerala, India**Dr. Navendu Page**, Wildlife Institute of India, Chandrabani, Dehradun, Uttarakhand, India**Dr. Kannan C.S. Warrier**, Institute of Forest Genetics and Tree Breeding, Tamil Nadu, India**Invertebrates****Dr. R.K. Avasthi**, Rohtak University, Haryana, India**Dr. D.B. Bastawade**, Maharashtra, India**Dr. Partha Pratim Bhattacharjee**, Tripura University, Suryamaninagar, India**Dr. Kailash Chandra**, Zoological Survey of India, Jabalpur, Madhya Pradesh, India**Dr. Ansie Dippenaar-Schoeman**, University of Pretoria, Queenswood, South Africa**Dr. Rory Dow**, National Museum of natural History Naturalis, The Netherlands**Dr. Brian Fisher**, California Academy of Sciences, USA**Dr. Richard Gallon**, Ilandudno, North Wales, LL30 1UP**Dr. Hemant V. Ghate**, Modern College, Pune, India**Dr. M. Monwar Hossain**, Jahangirnagar University, Dhaka, BangladeshFor Focus, Scope, Aims, and Policies, visit https://threatenedtaxa.org/index.php/JoTT/aims_scopeFor Article Submission Guidelines, visit <https://threatenedtaxa.org/index.php/JoTT/about/submissions>For Policies against Scientific Misconduct, visit https://threatenedtaxa.org/index.php/JoTT/policies_various

continued on the back inside cover

Cover: Stripe-necked Mongoose *Urva vitticolla* in poster colours, adapted from photograph by Ashni Dhawale, by Pooja Ramdas Patil.



Utilization of a new restoration technique for the rehabilitation of a degraded mangrove ecosystem: a case study from Koggala Lagoon, Sri Lanka

Mahanama Gamage Greshan Dhanushka¹ , Maduwe Guruge Manoj Prasanna² , Kariyawasam Marthinna Gamage Gehan Jayasuriya³  & Indupa Hasindi Vitanage⁴ 

¹ Wildlife and Ocean Resources Conservation Society, 121/3, Seethawaka Estate, Urugamuwa, Matara, Sri Lanka.

² Ministry of Environment, 414 1C, Robert Gunawardana Mw., Baththaramulla, Sri Lanka.

³ Department of Botany, University of Peradeniya, Peradeniya, Sri Lanka.

⁴ Young Zoologists' Association of Sri Lanka, National Zoological Gardens, Anagarika Dharmapala Mawatha, Dehiwala, Sri Lanka.

¹ mggdhanushka1981@yahoo.com, ² mprasanna74@yahoo.com, ³ gejaya@gmail.com, ⁴ hvitanage@gmail.com (corresponding author)

Abstract: Mangrove ecosystems, amongst the most productive and biologically complex on Earth, are being degraded worldwide, and their widespread decline during the past decades has affected vital ecosystem services. Mangroves at Koggala lagoon on the southern coast of Sri Lanka have been degraded at an alarming rate due to agricultural practices, coastal zone development, and tourism activities. Most of the banks are heavily eroded due to boat and sea plane activities, and the mangrove ecosystem has been significantly damaged. Implementation of a scientific rehabilitation project was needed to restore this degraded mangrove ecosystem, and research was carried out to enrich the mangrove community by re-establishing mangroves on the eroded banks using corrosion-resistant plastic barrels. The sustainability of replanted mangroves was monitored under phase one and the re-establishment of ecological functions in the mangrove community was monitored under phase two. The accumulated biomass carbon during the period of two and half years was calculated by an allometric equation suggested for calculating biomass carbon of mangroves using the girth and height of individuals. The highest rate of girth increment was observed by the 24th month from establishment, whilst the growth rate declined between the 18th and the 30th months. During the study period, the average above-ground and below-ground biomass per barrel showed a linear increment. Our case study showed that the new method used for restoration is successful in establishing mangroves in sites with high erosion. This restoration technique was successful in coping with the situation in Koggala lagoon where previous restoration attempts were failures. Thus, we recommend this restoration method for sites facing the threat of severe erosion.

Keywords: Allometric equations, carbon stocks, ecological function, eroded banks, growth rate, mangrove establishment, restoration technique.

Editor: Anonymity requested.

Date of publication: 26 September 2023 (online & print)

Citation: Dhanushka, M.G.G., M.G.M. Prasanna, K.M.G.G. Jayasuriya & I.H. Vitanage (2023). Utilization of a new restoration technique for the rehabilitation of a degraded mangrove ecosystem: a case study from Koggala Lagoon, Sri Lanka. *Journal of Threatened Taxa* 15(9): 23889–23897. <https://doi.org/10.11609/jott.8153.15.9.23889-23897>

Copyright: © Dhanushka et al. 2023. Creative Commons Attribution 4.0 International License. JoTT allows unrestricted use, reproduction, and distribution of this article in any medium by providing adequate credit to the author(s) and the source of publication.

Funding: Commercial Bank, MAS Intimates and INSEE Cement Corporation.

Competing interests: The authors declare no competing interests.



Our interest is in you

Author details: MAHANAMA GAMAGE GRESHAN DHANUSHKA serves as Chairman of Wildlife and oceans Resources Conservation Society. Actively contributes to the conservation and restoration of mangrove and coral reefs. Direct contribution to turtle conservation and awareness programmes is provided as well. MADUWE GURUGE MANOJ PRASANNA obtained his PhD from University of Peradeniya and currently working as project coordinator at Biodiversity Secretariat. Contributed several research programmes and published more than 10 research papers on mangrove ecology and its functions under the Biodiversity Secretariat. His major research area is mangrove ecology. KARIYAWASAM MARTHINNA GAMAGE GEHAN JAYASURIYA obtained his PhD from University of Kentucky and currently working as a professor in Botany in the Department of Botany, University of Peradeniya. Contributed to more than 35 SCI-indexed publications. His major research area is the seed biology of wild species assisting towards their conservation. INDUPA HASINDI VITANAGE obtained Diplomas in Palaeobiodiversity and Zooarchaeology from Postgraduate Institute of Archaeology, University of Kelaniya. Actively contributes to biodiversity conservation, related research and awareness programmes as a member of Young Zoologists' Association of Sri Lanka (YZA). Contributed to two publications.

Author contributions: M.G.G Dhanushka contributed to the study conception and design. Experimental arrangements and data collection were conducted by M.G.G Dhanushka. Data analysis was performed by K.M.G.G. Jayasuriya. The first draft of the manuscript was written by M.G.M. Prasanna, I.H. Vitanage and K.M.G.G. Jayasuriya and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Acknowledgements: The authors sincerely thank the principal sponsor, Commercial Bank and other sponsors, MAS Intimate, DER Touristik Foundation, and INSEE Cement Corporation for their faithful contribution towards the project. Furthermore, Trustees of the Commercial Bank CSR Trust, Coordinator - CSR Trust and the whole staff of CSR Unit, Alle Indrasobana Nayaka Thero of Thalathuduwa Aranya Senasana, L. J. Mendis Wickramasinghe, W.D. Dayawathi, Thilak Leelasena and Indika Sampath Ruwankumara are acknowledged for their valuable support.

INTRODUCTION

Mangroves are among the world's most productive and biologically complex ecosystems, acting as bridges between land and sea. Thriving in intertidal areas along tropical and subtropical coastlines, mangroves consist of salt-tolerant woody plant species and are commonly found in lagoons, bays, and estuaries (Prasanna & Ranawana 2014), including several locations in Sri Lanka (Ministry of Environment 2012). Mangroves provide a multitude of essential goods and services crucial for human well-being and survival. They play a crucial role in maintaining the ecological integrity of coastal zones and provide many ecosystem services categorized as provisioning, regulatory, supportive as well as cultural services (Donato et al. 2011; Feller et al. 2017). Carbon sequestration is one of the most significant services provided by mangroves, as they possess a remarkable capacity to capture and retain high amounts of carbon in the soil owing to high productivity compared to other terrestrial ecosystems (Alongi 2014). Consequently, mangroves contribute significantly to the reduction of greenhouse gases and aid climate change mitigation efforts. Despite their importance, mangrove ecosystems have suffered global degradation (Duke et al. 2017; Feller et al. 2017), resulting in the decline of their ecosystem services over the past decades. According to Mukherjee et al. (2014), approximately 60% of major global ecosystem services have been degraded either totally or partially.

Mangrove Ecosystems of Sri Lanka

Sri Lanka, a tropical island with numerous estuaries and lagoons, possesses a diverse range of mangrove ecosystems along its coastline (Edirisinghe et al. 2012). These mangrove ecosystems consist of two types of plant communities: true mangroves and mangrove associates. True mangroves are woody plants that exclusively occur in mangrove forests, displaying specific adaptations to the environment and physiological mechanisms to tolerate high salinity levels (Tomlinson 2016). In contrast, mangrove associates are primarily herbaceous plants found in terrestrial or aquatic habitats, but they can also be present within the mangrove ecosystem (Tomlinson 1986). Most Sri Lankan mangrove areas (92.6%) are confined to the dry and intermediate zones. Similar to the global situation, Sri Lankan mangroves were also degraded especially during the last four decades due to various anthropogenic activities (Wickramasinghe et al. 2022).

Nevertheless, mangrove research and rehabilitation

efforts have progressed steadily over the last several decades as the importance of mangrove ecosystems has been better understood and documented. Furthermore, the mangrove ecosystems are considered a predominantly important ecosystem for coastal communities due to their provision of ecosystem services, such as supplying timber and fuel wood, supporting fisheries, sediment trapping, coastal defence and carbon storage (Donato et al. 2011; Feller et al. 2017). Amongst all the ecosystems across the tropics, mangrove ecosystems are considered one of the most threatened (Duke et al. 2017) mainly due to impacts from anthropogenic activities including conversion to agriculture and aquaculture as well as urbanisation and pollution (Feller et al. 2017). Under these circumstances, huge efforts are being put into mangrove rehabilitation and restoration in degraded areas. Though, such large-scale efforts are generally unsuccessful due to various reasons such as poor species selection, inappropriate location selection and poor knowledge of mangrove ecology as well as physiology (Kodikara et al. 2017). However, when elements of species biology and hydrological requirements are incorporated into the design and implementation of rehabilitation projects with an appropriate knowledge base, some efforts are becoming more successful (Feller et al. 2017).

Status of Koggala Lagoon mangrove ecosystem

The Koggala lagoon is situated in the Southern province of Sri Lanka, specifically between 5°58'–6°20' N & 80°17'–80°22' E. It encompasses an area of 727 ha and consists of 14 islets (IUCN and Central Environmental Authority, 2006; Gunaratne et al. 2010). Several tributaries, including the Koggala Oya, provide freshwater input to the lagoon. The hydrology and water quality of the lagoon, including salinity and pH, are influenced by heavy rainfall and the characteristics of the lagoon mouth due to its location in the wet zone of the country. Previous studies have reported the presence of 10 true mangrove species in the lagoon. However, the classification of *Acrosticum aurium* and *Dolichandrone spathacia* as true mangroves by IUCN and Central Environmental Authority (2006) is disputed by the experts' team of the National Red List (2012), who considers them as mangrove associates. Therefore, the number of true mangrove species identified in the lagoon is recognized as eight. Mangroves are found in a narrow strip surrounding the lagoon's islands and along the stream banks. Unfortunately, due to activities such as boating and sea plane landing, and take-off, many of the banks have undergone degradation and significant

erosion, leading to substantial damage to the mangrove ecosystems in the area.

The structure of the lagoon mouth has changed since 1990 due to the removal of the natural sand barrier (Gunarathne 2011). Consequently, sand started to deposit on the river mouth and the bridge over Pol Oya in Galle-Matara main road, blocking the water flow. A rubble mound groyne system (old groyne) was built in 1997 to prevent the issue. Due to this artificial construction, erosion of the lagoon bank became threatened as the Galle-Matara main road and bridge became vulnerable to sea erosion. Another groyne (new groyne) (Image 1) was established in 2005 to control the said situation (Gunarathne 2011). The outlet (Image 2) has been diverted westward creating an approximately 30–40 m wide open passage to the sea consequently (Gunawickrama & Chandana 2006).

The construction of an artificially built groyne in the Koggala lagoon initially resulted in a reduction of sand deposition. However, it also led to seawater intrusion into the lagoon (Gunawickrama & Chandana 2006). Over time, sand deposition resumed at the river mouth, causing water blockage and a subsequent decrease in water salinity and a rise in water level. The increased water level further contributed to bank erosion within the lagoon. These degraded banks, characterized by high erosion and stream flow, present challenges for natural regeneration and make it impossible to rehabilitate the mangrove community. Additionally, the degradation and heavy erosion of the banks caused by boating and seaplane activities further exacerbate the problem. Despite previous attempts at planting mangrove seedlings in the Koggala lagoon, the general approach has failed multiple times in recent years. Natural regeneration has not been observed in the degraded banks of the lagoon, necessitating a new restoration approach and the implementation of a continuous monitoring mechanism to ensure the success of mangrove restoration. Therefore, the primary objective of the study was to enhance the mangrove community in the Koggala lagoon using a technique suitable for the prevailing conditions in the lagoon.

METHODS

Establishment of the restoration trail

A controlled plot using general restoration processes could not be established due to the unsuitable ground conditions and heavy erosion of the lagoon banks. A new restoration approach was designed to support restored

plants to withstand the bank erosion. In this approach mangrove saplings were planted in plastic barrels.

Empty and well-cleaned chemical plastic barrels (~38 cm diameter and ~79 cm height) were gathered from factories located in the area. The top and bottom of all the barrels were removed. Thirty seven of these barrels were placed in holes excavated in eroded banks of three islands: Thalathuduwa, Kuruluduwa (Image 3) and Ganduwa. Barrels were placed with 60–90 cm spacing between each other, covering ~600 m stretch of the banks. The barrels were filled with soil excavated from the same restoration site. Two true mangrove species occurring in the area, *Rhizophora mucronata* and *R. apiculata* were selected as restoring species for this pilot study. These two species were selected as they contain large numbers of prop and stilt roots which assist in the proper establishment of the plant in the planted site. The availability of diaspores at the time of nursery establishment was also considered. Four *R. mucronata* saplings (~20–35 cm height) and one *R. apiculata* sapling (~20–35 cm height) were planted in each barrel. Saplings were raised in a nearby nursery using the diaspores collected from trees in the existing vegetation of the Koggala lagoon.

Maintenance and monitoring

Planted seedlings were observed weekly during the first six months, and later monthly. Dead saplings were not replaced as it would affect the final analysis. There was no need to replenish the soil, as the soil in the barrels was not eroded during the period (Image 4). The diameter at breast height (dbh) and height of each sapling in each barrel were recorded on the first day of planting and then after every six months for two and half years. Monthly measurements were not taken as the changes in girth and height were not significant within a month.

Data analysis

Height and dbh increments were separately plotted against time. A logistic four-parameter sigmoidal curve was fitted to determine the pattern of growth (Tsoularis 2001). The growth rate based on height and dbh was calculated separately for six months period from the initial planting date to August 2020. Accumulated biomass carbon during the period of two and half years was calculated using the dbh and height of the individuals with an allometric equation suggested for calculating biomass carbon of mangroves.

Above ground biomass (AGB) for *Rhizophora mucronata*,



Image 1. Satellite image of lagoon outlet with the existing groyne structures in 2010 (Source: Google Earth Pro 2022).



Image 2. The present situation of Koggala Lagoon mouth (Source: Google Earth Pro 2022).



Image 3. First mangrove planting in Kurulu Duwa island in July 2018.



Image 4. The soil in the barrels was not eroded even after a year from planting, another mangrove hedge was planted in barrels parallel to the previous mangrove hedge.

$\log_e(\text{AGB}) = 6.247 + 2.64 \log_e(\text{dbh})$ (Amarasinghe & Balasubramaniam 1992b)
 and for *Rhizophora apiculata*,
 $\text{AGB} = 0.251 \rho \text{ dbh}^{2.46}$ (Komiyama et al. 2005)
 Below ground biomass (BGB) for both species,
 $\text{BGB} = 0.199 \rho^{0.899} \text{ dbh}^{2.46}$ (Komiyama et al. 2005)

RESULTS

Survival of plants during the two-and-a-half years of the monitoring period

After the first six months of establishment, all the *R. mucronata* and *R. apiculata* saplings survived in the study site. Within the next six months period, more *R. apiculata* saplings died compared to *R. mucronata* saplings. After 18 months of establishment, 85 % of the *R. mucronata* and 67 % of *R. apiculata* saplings survived (Figure 1). Thereafter, none of the remaining saplings died during the observation period of 30 months.

Growth of established saplings

The height of both *R. mucronata* and *R. apiculata* increased gradually with time, following a sigmoidal curve as expected (Figure 2). However, the height increment of *R. apiculata* was slightly higher than that of *R. mucronata*. The dbh of the saplings of both species increased with time in a similar pattern (Figure 3). dbh increment of *R. apiculata* was also higher than that of *R. mucronata*.

The height increment rate of *R. apiculata* was higher than that of *R. mucronata* throughout the observational period (Figure 4A). However, during the first 12 months period, the dbh increment rate of *R. mucronata* was higher than that of *R. apiculata*, whereas, during the rest of the period, the dbh increment rate of *R. apiculata* was slightly higher than *R. mucronata* (Figure 4B). The rate of height increment of the two species increased with time until the 18th month from the establishment and started to decline thereafter. Thus, the highest rate of height increment was observed by the 18th month of the establishment. The highest rate of dbh increment was observed by the 24th month from establishment whilst the increment rate declined between the 18th–30th month from establishment.

Biomass Carbon accumulation by the established stand

The average above-ground and below-ground biomass per barrel showed a linear increment during the study period (Figure 5). At the end of the study period, the average above-ground biomass per barrel was 70.7 ± 11.7 kg. This biomass included 29.7 ± 4.9 kg of carbon and it is equivalent to 108.2 ± 17.9 kg of CO_2 . Below ground biomass content at the time of final observation was 35.0 ± 5.8 kg per barrel. This included 14.7 ± 2.4 kg of carbon and equivalent to 53.5 ± 8.3 kg of CO_2 . By the end of the study period, plants have accumulated 105.8 ± 17.5 kg of biomass per barrel which contained 44.4 ± 7.3 kg of carbon per barrel and which is equivalent to 161.7 ± 26.8 kg of CO_2 . Thus, these plants have sequestered 217.15 tonnes of carbon per hectare, which is equivalent to 788.1 tonnes of CO_2 per hectare.

According to the calculations up to the final sampling date, the study site has accumulated 2,619.5 kg, 1294.5 kg and 3,914.9 kg of above-ground, below-ground and total biomass respectively. Furthermore, the total biomass accumulated up to the final monitoring date included 1,643.9 kg of carbon which is equivalent to 5,983.9 kg of CO_2 .

However, up to the end of the monitoring period, no natural recolonization was observed in the restored area.

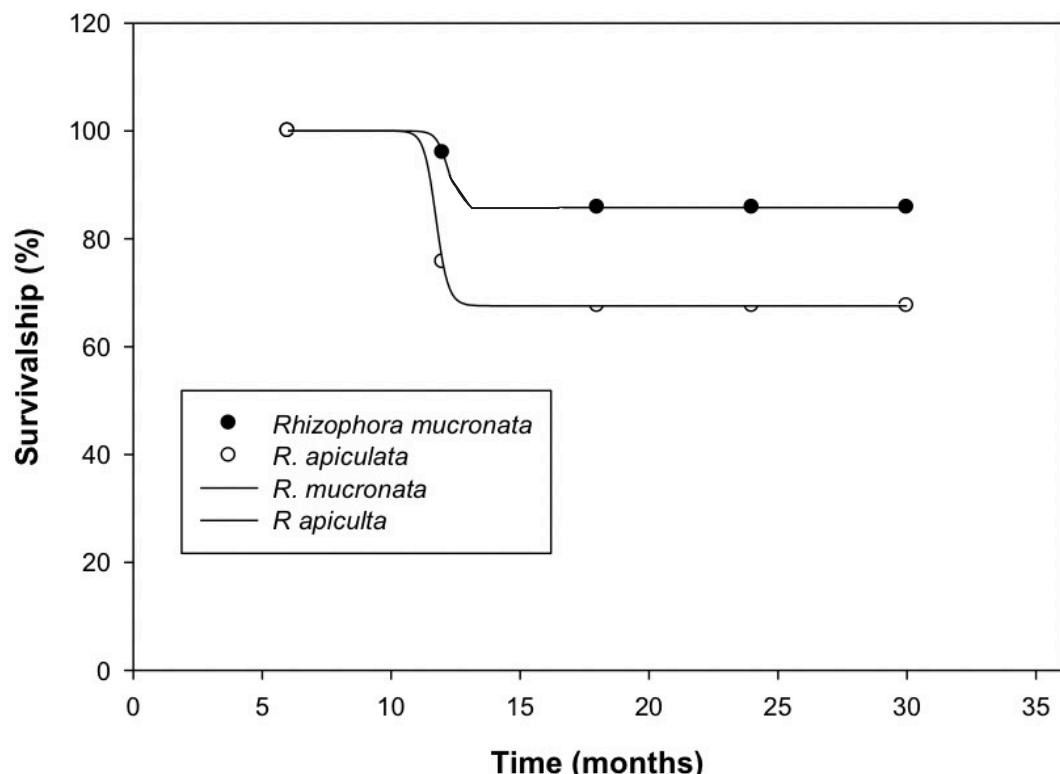


Figure 1. Survival percentage of *Rhizophora mucronata* and *R. apiculata* saplings during the 30th months of the observation period. Four-parameter logistic curves were fitted to observe the pattern of survival.

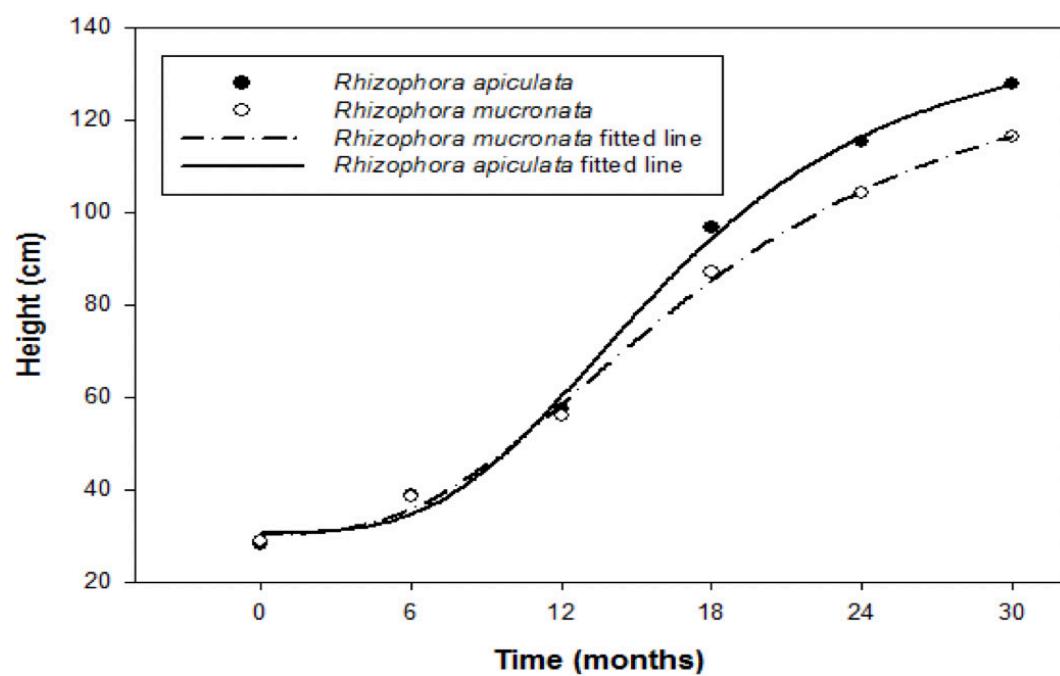


Figure 2. Height increment of *Rhizophora mucronata* and *R. apiculata* saplings against time, during the monitoring period. Four-parameter logistic sigmoidal curves were fitted to determine the pattern of height increment.

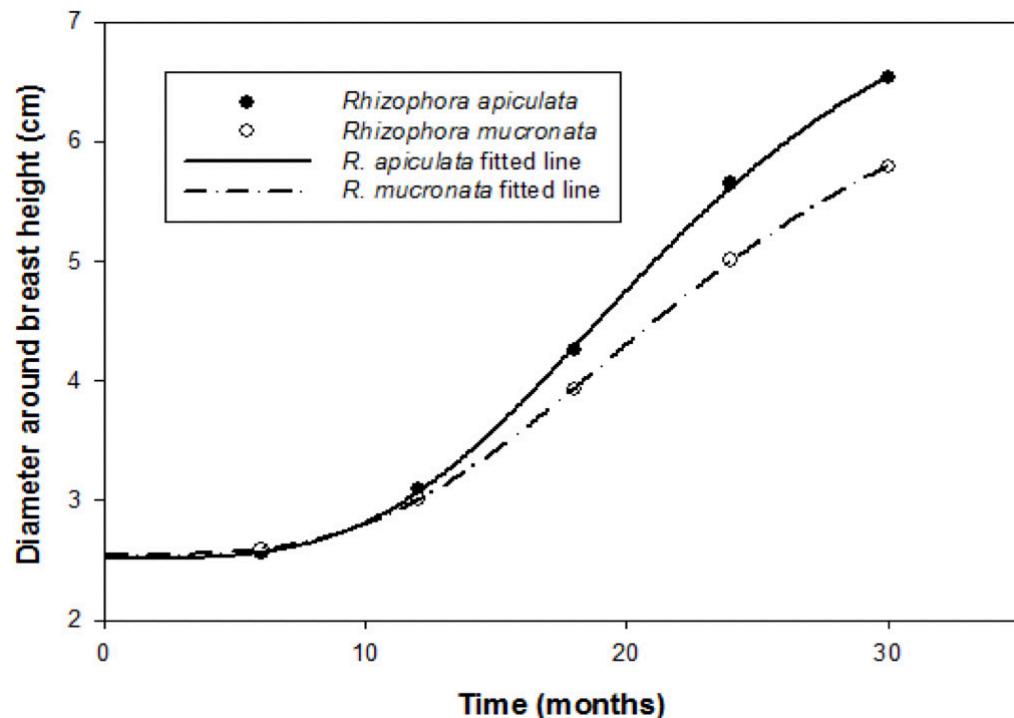


Figure 3. Diameter at breast height increment of *Rhizophora mucronata* and *R. apiculata* saplings during the monitoring period. Four parameter logistic sigmoidal curves were fitted to determine the pattern of height increment.

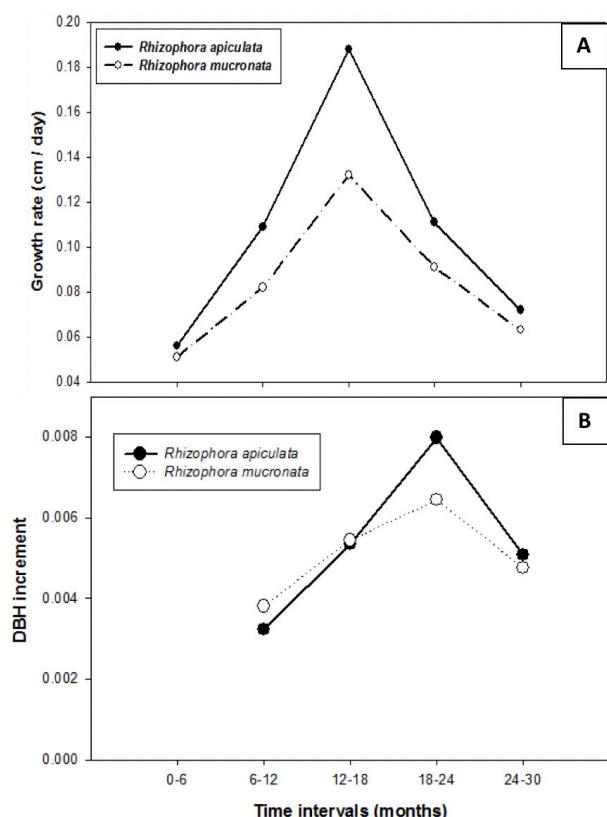


Figure 4. A—Height increment rate | B—girth increment rate of *Rhizophora mucronata* and *R. apiculata* were established in barrels in the Koggala lagoon.

DISCUSSION

The results of this study indicate the success of the restoration technique employed, as evidenced by the high survival rates of the restored species after a substantial period since the establishment (2½ years). The observed survival rates of 85% for *R. mucronata* saplings and 65% for *R. apiculata* suggest the effectiveness of the restoration approach.

Comparison with previous trials conducted without a controlled plot revealed a significant improvement in sapling survival. In contrast to previous attempts, where none of the saplings survived for more than a year, the current restoration technique demonstrated higher success rates. These findings align with research conducted by Kodikara et al. (2017) on mangrove restoration projects in Sri Lanka, where most restored sites exhibited less than 50% survival, and only a small number surpassed this threshold. Thus, the higher sapling survival rates observed at the Koggala mangrove restoration site indicate a comparative success compared to other restoration efforts.

Sapling growth analysis showed that saplings of both species used have normal sigmoidal growth patterns and they were reaching the maturity level. Especially, the reduction in growth rate during the 24th–30th month of

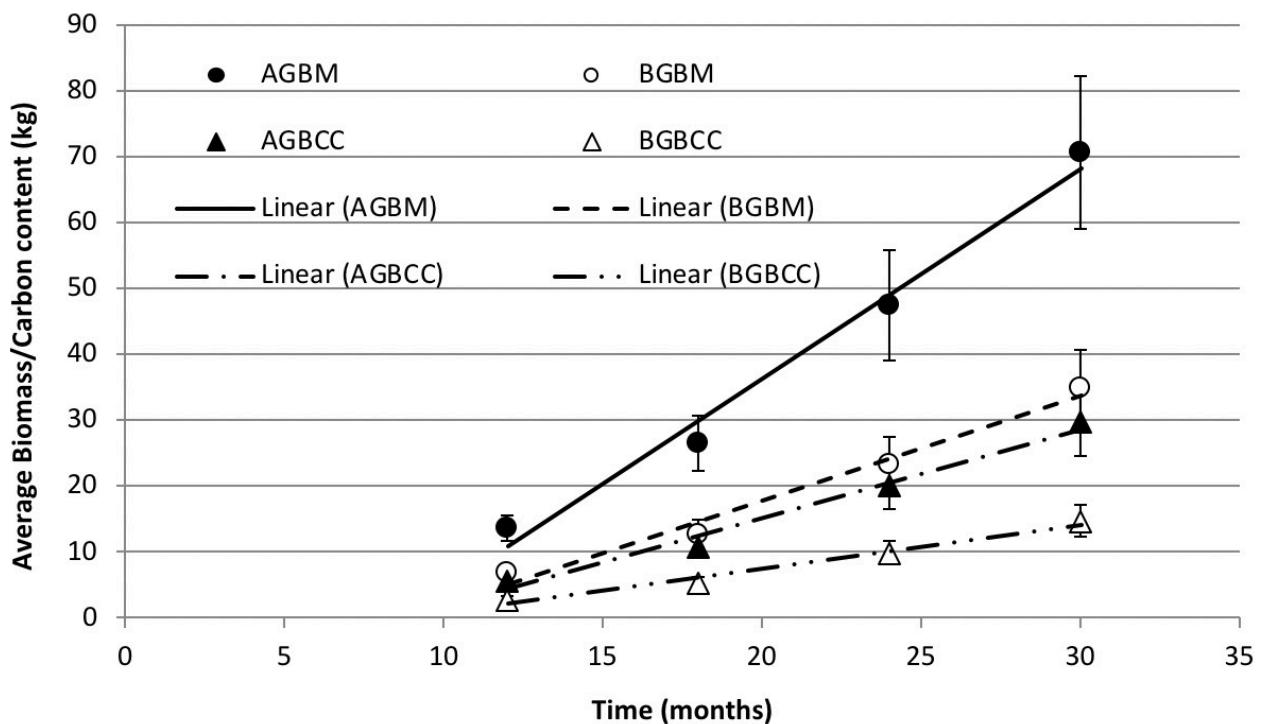


Figure 5. Average biomass and carbon accumulation of the established plant with time. Error bars are \pm SE.



© Dhanushka Mahanama

Image 5. Mangrove plants after forty-five months from planting.

establishment shows that these saplings were gradually reaching the matured stage. Thus, it seems that the plants have well established within the restored sites.

The restoration of the mangrove site demonstrated a significant potential for carbon sequestration, with an observed carbon sequestration rate of 217.15 tonnes per ha (equivalent to 788.1 tonnes of CO_2 per ha), highlighting its contribution to reducing atmospheric CO_2 levels.

However, it cannot be compared with the total carbon content reported in other mangroves. However, the above-ground biomass carbon content of the restored site (128.8 t per ha) was higher than the average above-ground carbon content for global mangroves (78 t of carbon per ha; Estrada & Soares 2017), Mahanadi Mangrove, India (Sahu et al. 2016), and Negombo estuary (80.5 t of carbon per ha; Perera et al. 2018). This value



is slightly lower than that was reported for Batticaloa lagoon (131 t of carbon per ha; Perera et al. 2018) in Sri Lanka. These unusually high values may have been caused due to lower planting spacing of the restoration site than the usual spacing of a natural mangrove community. Further, the used spacing in the current study is less than the recommended spacing between mangrove seedlings planting for restoration (80–120 cm recommended [International Coral Reef Initiative and Pole-Relais, Zones Humides Tropicales, 2020] vs. 60–90 in the current study). Thus, thinning of the mangrove vegetation of the restored site may be required to allow the saplings to grow in their usual manner.

Our analysis showed a higher growth rate in *R. apiculata* compared to *R. mucronata* when considering the dbh and height. This could be due to the genetic potential of the two species as the same type of observation has been reported by Nit et al. (2011). However, further studies are needed to conclude the growth rates of the two species.

Our case study showed that the new method of mangrove restoration is successful in establishing mangroves in sites facing high erosion (Image 5). Especially, it seems that the new method is successful in coping with the situation in the Koggala lagoon as previous normal restoration trials conducted on this site failed. Thus, we recommend this restoration method for sites facing the threat of severe erosion.

REFERENCES

Alongi, D.M. (2014). Carbon sequestration in mangrove forests. *Carbon Management* 3(3): 313–322.

Donato, D.C., J.B. Kauffman, D. Murdiyarno, S. Kurnianto, M. Stidham & M. Kanninen (2011). Mangroves among the most carbon-rich forests in the tropics. *Journal of Nature Geoscience* 4: 293–297.

Duke, N.C., J.M. Kovacs, A. Griffith, L. Preece, D.J. Hill, P. Oosterzee, J. Mackenzie, H.S. Morning & D. Burrows (2017). Large-scale dieback of mangroves in Australia's Gulf of Carpentaria: a severe ecosystem response, coincidental with an unusually extreme weather event. *Journal of Marine and Freshwater Research* 68(10): 1816–1829. <https://doi.org/10.1071/MF16322>

Edirisinghe, E.A.P.N., K.P. Ariyadasa & R.P.D.S. Chandani (2012). Forest Cover Assessment of Sri Lanka. *The Sri Lankan Forester* 34: 1–12.

Estrada, G.C.D. & M.L.G. Soares (2017). Global patterns of aboveground carbon stock and sequestration in mangroves. *Annals of the Brazilian Academy of Sciences* 89(2): 973–989. <https://doi.org/10.1590/0001-3765201720160357>

Feller, I.C., D.A. Friess, K.W. Krauss & R.R. Lewis III (2017). The state of the world's mangroves in the 21st century under climate change. *Journal of Hydrobiologia* 803: 1–12. <https://doi.org/10.1007/s10750-017-3331-z>

Gunaratne, G.L., L. Tanaka, G.P. Amarasekara, T. Priyadarshana & J. Manatunge (2011). Impact of rubble mound groyne structural interventions in restoration of Koggala lagoon, Sri Lanka; numerical modelling approach. *Journal of Coast Conservation* 15: 113–121. <https://doi.org/10.1007/s11852-010-0125-0>

Gunawickrama, K.B.S. & E.P.S. Chandana (2006). Some Hydrographic aspects of Koggala Lagoon with preliminary results on distribution of the marine bivalve *Saccostrea forskalli*: pre-tsunami status. *Ruhuna Journal of Science* 1: 16–23.

Kodikara, K.A.S., N. Mukherjee, L.P. Jayatissa, F. Dahdouh-Guebas & N. Koedam (2017). Have mangrove restoration projects worked? An in-depth study in Sri Lanka. *Restoration Ecology* 25: 705–716. <https://doi.org/10.1111/rec.12492>

<http://dx.doi.org/10.1111/j.1442-9993.2012.02492.x>
Ministry of Environment (2012). *The National Red List 2012 of Sri Lanka; Conservation Status of the Fauna & Flora.* Ministry of Environment, Colombo, Sri Lanka. viii + 476 pp.

Colombo, Sri Lanka, VIII + 470 pp.
Mukherjee, N., W.J. Sutherland, L. Dicks, J. Huge, N. Koedam & F. Dahdouh-Guebas (2014). Ecosystem Service Valuations of Mangrove Ecosystems to Inform Decision Making and Future Valuation Exercises. *PLoS ONE* 9(9): e107706. <https://doi.org/10.1371/journal.pone.0111386>

Nit, L.B.E. & P.P. Abit (2011). Growth and survival of mangrove seedlings under different levels of salinity and drought stress. *Annals of Tropical Research* 33(2): 107–129.

Perera, K.A.R.S., K.H.W.L. De Silva & M.D. Amarasinghe (2018). Potential Impact of Predicted Sea-Level Rise on Carbon Sink Function of Mangrove Ecosystems with Special Reference to Negombo Estuary, Sri Lanka. *Journal of Global and Planetary Change* 161: 162–177.

Prasanna, M.G.M. & K.B. Ranawana (2014). *Guide to Mangroves of Sri Lanka*. Biodiversity Secretariat, Ministry of Environment and Renewable Energy, Battaramulla, Sri Lanka, 70 pp.

Prasanna, M.G.M., K.B. Ranawana, K.M.G.G. Jayasuriya, P. Abeykoon

Prasanna, K.N.D., K.D. Ranawana, K.M.G. Jayasuriya, V. Asley, S.C. & M. Ranasinghe (2017). Mangrove Species Distribution, Diversity and Present Status in the North and East Coast of Sri Lanka. *Journal of Wild Lanka* 5(3): 90–98.

Sahu, S.C., M. Kumar & N.H. Ravidranath (2016). Carbon Stocks in Natural and Planted Mangrove forests of Mahanadi Mangrove Wetland, East Coast of India. *Current Science* 110(12): 2253–2260. <https://doi.org/10.18520/cs/v110/i12/2334-2341>

Tomlinson, P.B. (1986). *The Botany of Mangroves*. Cambridge University Press, Cambridge, 225 pp.

Tomlinson, P.B. (2016). *The Botany of Mangroves 2*. Cambridge University

Press, Cambridge, 436 pp.
Tsoularis, A. (2001). Analysis of logistic growth models. *Research Letters in the Mathematical Sciences* 1(1), 1–10.

in the *Information and Mathematical Sciences* 2: 23–46.

Wickramasinghe, S., M. Wijesinghe & C. Sarathchandra (2022). Sri Lankan Mangroves: Biodiversity, Livelihoods, and Conservation, pp. 297–329. In: Das, S.C., Pullaiah & E.C. Ashton, (eds.). *Mangroves: Biodiversity, Livelihoods and Conservation*. Springer, Singapore, 461 pp.



Sinhala abstract:

Mr. Jatishwor Singh Irungbam, Biology Centre CAS, Branišovská, Czech Republic.
Dr. Ian J. Kitching, Natural History Museum, Cromwell Road, UK
Dr. George Mathew, Kerala Forest Research Institute, Peechi, India
Dr. John Noyes, Natural History Museum, London, UK
Dr. Albert G. Orr, Griffith University, Nathan, Australia
Dr. Sameer Padhye, Katholieke Universiteit Leuven, Belgium
Dr. Nancy van der Poorten, Toronto, Canada
Dr. Karen Schnabel, NIWA, Wellington, New Zealand
Dr. R.M. Sharma, (Retd.) Scientist, Zoological Survey of India, Pune, India
Dr. Manju Siliwal, WILD, Coimbatore, Tamil Nadu, India
Dr. G.P. Sinha, Botanical Survey of India, Allahabad, India
Dr. K.A. Subramanian, Zoological Survey of India, New Alipore, Kolkata, India
Dr. P.M. Sureshan, Zoological Survey of India, Kozhikode, Kerala, India
Dr. R. Varatharajan, Manipur University, Imphal, Manipur, India
Dr. Eduard Vives, Museu de Ciències Naturals de Barcelona, Terrassa, Spain
Dr. James Young, Hong Kong Lepidopterists' Society, Hong Kong
Dr. R. Sundararaj, Institute of Wood Science & Technology, Bengaluru, India
Dr. M. Nithyanandan, Environmental Department, La Al Kuwait Real Estate. Co. K.S.C., Kuwait
Dr. Himender Bharti, Punjabi University, Punjab, India
Mr. Purnendu Roy, London, UK
Dr. Saito Motoki, The Butterfly Society of Japan, Tokyo, Japan
Dr. Sanjay Sondhi, TITLI TRUST, Kalpavriksh, Dehradun, India
Dr. Nguyen Thi Phuong Lien, Vietnam Academy of Science and Technology, Hanoi, Vietnam
Dr. Nitin Kulkarni, Tropical Research Institute, Jabalpur, India
Dr. Robin Wen Jiang Ngiam, National Parks Board, Singapore
Dr. Lional Monod, Natural History Museum of Geneva, Genève, Switzerland.
Dr. Asheesh Shivam, Nehru Gram Bharti University, Allahabad, India
Dr. Rosana Moreira da Rocha, Universidade Federal do Paraná, Curitiba, Brasil
Dr. Kurt R. Arnold, North Dakota State University, Saxony, Germany
Dr. James M. Carpenter, American Museum of Natural History, New York, USA
Dr. David M. Claborn, Missouri State University, Springfield, USA
Dr. Karen Schnabel, Marine Biologist, Wellington, New Zealand
Dr. Amazonas Chagas Júnior, Universidade Federal de Mato Grosso, Cuiabá, Brasil
Mr. Monsoon Jyoti Gogoi, Assam University, Silchar, Assam, India
Dr. Heo Chong Chin, Universiti Teknologi MARA (UiTM), Selangor, Malaysia
Dr. R.J. Shiel, University of Adelaide, SA 5005, Australia
Dr. Siddharth Kulkarni, The George Washington University, Washington, USA
Dr. Priyadarshan Dharma Rajan, ATREE, Bengaluru, India
Dr. Phil Alderslade, CSIRO Marine And Atmospheric Research, Hobart, Australia
Dr. John E.N. Veron, Coral Reef Research, Townsville, Australia
Dr. Daniel Whitmore, State Museum of Natural History Stuttgart, Rosenstein, Germany.
Dr. Yu-Feng Hsu, National Taiwan Normal University, Taipei City, Taiwan
Dr. Keith V. Wolfe, Antioch, California, USA
Dr. Siddharth Kulkarni, The Hormiga Lab, The George Washington University, Washington, D.C., USA
Dr. Tomas Ditrich, Faculty of Education, University of South Bohemia in Ceske Budejovice, Czech Republic
Dr. Mihaly Foldvari, Natural History Museum, University of Oslo, Norway
Dr. V.P. Uniyal, Wildlife Institute of India, Dehradun, Uttarakhand 248001, India
Dr. John T.D. Caleb, Zoological Survey of India, Kolkata, West Bengal, India
Dr. Priyadarshan Dharma Rajan, Ashoka Trust for Research in Ecology and the Environment (ATREE), Royal Enclave, Bangalore, Karnataka, India

Fishes

Dr. Neelesh Dahanukar, IISER, Pune, Maharashtra, India
Dr. Topiltzin Contreras MacBeath, Universidad Autónoma del estado de Morelos, México
Dr. Heok Hee Ng, National University of Singapore, Science Drive, Singapore
Dr. Rajeev Raghavan, St. Albert's College, Kochi, Kerala, India
Dr. Robert D. Sluka, Chiltern Gateway Project, A Rocha UK, Southall, Middlesex, UK
Dr. E. Vivekanandan, Central Marine Fisheries Research Institute, Chennai, India
Dr. Davor Zanella, University of Zagreb, Zagreb, Croatia
Dr. A. Biju Kumar, University of Kerala, Thiruvananthapuram, Kerala, India
Dr. Akhilesh K.V., ICAR-Central Marine Fisheries Research Institute, Mumbai Research Centre, Mumbai, Maharashtra, India
Dr. J.A. Johnson, Wildlife Institute of India, Dehradun, Uttarakhand, India
Dr. R. Ravinesh, Gujarat Institute of Desert Ecology, Gujarat, India

Amphibians

Dr. Sushil K. Dutta, Indian Institute of Science, Bengaluru, Karnataka, India
Dr. Annemarie Ohler, Muséum national d'Histoire naturelle, Paris, France

Reptiles

Dr. Gernot Vogel, Heidelberg, Germany
Dr. Raju Vyas, Vadodara, Gujarat, India
Dr. Pritpal S. Soorae, Environment Agency, Abu Dhabi, UAE.
Prof. Dr. Wayne J. Fuller, Near East University, Mersin, Turkey
Prof. Chandrashekher U. Rironker, Goa University, Taleigao Plateau, Goa, India
Dr. S.R. Ganesh, Chennai Snake Park, Chennai, Tamil Nadu, India
Dr. Himansu Sekhar Das, Terrestrial & Marine Biodiversity, Abu Dhabi, UAE

Journal of Threatened Taxa is indexed/abstracted in Bibliography of Systematic Mycology, Biological Abstracts, BIOSIS Previews, CAB Abstracts, EBSCO, Google Scholar, Index Copernicus, Index Fungorum, JournalSeek, National Academy of Agricultural Sciences, NewJour, OCLC WorldCat, SCOPUS, Stanford University Libraries, Virtual Library of Biology, Zoological Records.

NAAS rating (India) 5.64

Birds

Dr. Hem Sagar Baral, Charles Sturt University, NSW Australia
Mr. H. Biju, Coimbatore, Tamil Nadu, India
Dr. Chris Bowden, Royal Society for the Protection of Birds, Sandy, UK
Dr. Priya Davidar, Pondicherry University, Kalapet, Puducherry, India
Dr. J.W. Duckworth, IUCN SSC, Bath, UK
Dr. Rajah Jayopal, SACON, Coimbatore, Tamil Nadu, India
Dr. Rajiv S. Kalsi, M.L.N. College, Yamuna Nagar, Haryana, India
Dr. V. Santharam, Rishi Valley Education Centre, Chittoor Dt., Andhra Pradesh, India
Dr. S. Balachandran, Bombay Natural History Society, Mumbai, India
Mr. J. Praveen, Bengaluru, India
Dr. C. Srinivasulu, Osmania University, Hyderabad, India
Dr. K.S. Gopi Sundar, International Crane Foundation, Baraboo, USA
Dr. Gombobaatar Sundev, Professor of Ornithology, Ulaanbaatar, Mongolia
Prof. Reuven Yosef, International Birding & Research Centre, Eilat, Israel
Dr. Taej Mundkur, Wetlands International, Wageningen, The Netherlands
Dr. Carol Inskip, Bishop Auckland Co., Durham, UK
Dr. Tim Inskip, Bishop Auckland Co., Durham, UK
Dr. V. Gokula, National College, Tiruchirappalli, Tamil Nadu, India
Dr. Arkady Lelej, Russian Academy of Sciences, Vladivostok, Russia
Dr. Simon Dowell, Science Director, Chester Zoo, UK
Dr. Mário Gabriel Santiago dos Santos, Universidade de Trás-os-Montes e Alto Douro, Quinta de Prados, Vila Real, Portugal
Dr. Grant Connette, Smithsonian Institution, Royal, VA, USA
Dr. P.A. Azeez, Coimbatore, Tamil Nadu, India

Mammals

Dr. Giovanni Amori, CNR - Institute of Ecosystem Studies, Rome, Italy
Dr. Anwaruddin Chowdhury, Guwahati, India
Dr. David Mallon, Zoological Society of London, UK
Dr. Shomita Mukherjee, SACON, Coimbatore, Tamil Nadu, India
Dr. Angie Appel, Wild Cat Network, Germany
Dr. P.O. Nameer, Kerala Agricultural University, Thrissur, Kerala, India
Dr. Ian Redmond, UNEP Convention on Migratory Species, Lansdown, UK
Dr. Heidi S. Riddle, Riddle's Elephant and Wildlife Sanctuary, Arkansas, USA
Dr. Karin Schwartz, George Mason University, Fairfax, Virginia.
Dr. Lala A.K. Singh, Bhubaneswar, Orissa, India
Dr. Mewa Singh, Mysore University, Mysore, India
Dr. Paul Racey, University of Exeter, Devon, UK
Dr. Honnavalli N. Kumara, SACON, Anaikatty P.O., Coimbatore, Tamil Nadu, India
Dr. Nishith Dharaiya, HNG University, Patan, Gujarat, India
Dr. Spartaco Gippoliti, Socio Onorario Società Italiana per la Storia della Fauna "Giuseppe Altobello", Rome, Italy
Dr. Justus Joshua, Green Future Foundation, Tiruchirappalli, Tamil Nadu, India
Dr. H. Raghuram, The American College, Madurai, Tamil Nadu, India
Dr. Paul Bates, Harison Institute, Kent, UK
Dr. Jim Sanderson, Small Wild Cat Conservation Foundation, Hartford, USA
Dr. Dan Challender, University of Kent, Canterbury, UK
Dr. David Mallon, Manchester Metropolitan University, Derbyshire, UK
Dr. Brian L. Cypher, California State University-Stanislaus, Bakersfield, CA
Dr. S.S. Talmale, Zoological Survey of India, Pune, Maharashtra, India
Prof. Karan Bahadur Shah, Budhanilkantha Municipality, Kathmandu, Nepal
Dr. Susan Cheyne, Borneo Nature Foundation International, Palangkaraya, Indonesia
Dr. Hemanta Kafley, Wildlife Sciences, Tarleton State University, Texas, USA

Other Disciplines

Dr. Aniruddha Belsare, Columbia MO 65203, USA (Veterinary)
Dr. Mandar S. Paingankar, University of Pune, Pune, Maharashtra, India (Molecular)
Dr. Jack Tordoff, Critical Ecosystem Partnership Fund, Arlington, USA (Communities)
Dr. Ulrike Streicher, University of Oregon, Eugene, USA (Veterinary)
Dr. Hari Balasubramanian, EcoAdvisors, Nova Scotia, Canada (Communities)
Dr. Rayanna Helleni Santos Bezerra, Universidade Federal de Sergipe, São Cristóvão, Brazil
Dr. Jamie R. Wood, Landcare Research, Canterbury, New Zealand
Dr. Wendy Collinson-Jonker, Endangered Wildlife Trust, Gauteng, South Africa
Dr. Rajeshkumar G. Jani, Anand Agricultural University, Anand, Gujarat, India
Dr. O.N. Tiwari, Senior Scientist, ICAR-Indian Agricultural Research Institute (IARI), New Delhi, India
Dr. L.D. Singla, Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana, India
Dr. Rupika S. Rajakaruna, University of Peradeniya, Peradeniya, Sri Lanka
Dr. Bharat Baviskar, Wild-CER, Nagpur, Maharashtra 440013, India

Reviewers 2020–2022

Due to paucity of space, the list of reviewers for 2018–2020 is available online.

The opinions expressed by the authors do not reflect the views of the Journal of Threatened Taxa, Wildlife Information Liaison Development Society, Zoo Outreach Organization, or any of the partners. The journal, the publisher, the host, and the partners are not responsible for the accuracy of the political boundaries shown in the maps by the authors.

Print copies of the Journal are available at cost. Write to:
The Managing Editor, JoTT,
c/o Wildlife Information Liaison Development Society,
43/2 Varadarajulu Nagar, 5th Street West, Ganapathy, Coimbatore,
Tamil Nadu 641006, India
ravi@threatenedtaxa.org



OPEN ACCESS



The Journal of Threatened Taxa (JoTT) is dedicated to building evidence for conservation globally by publishing peer-reviewed articles online every month at a reasonably rapid rate at www.threatenedtaxa.org. All articles published in JoTT are registered under [Creative Commons Attribution 4.0 International License](#) unless otherwise mentioned. JoTT allows unrestricted use, reproduction, and distribution of articles in any medium by providing adequate credit to the author(s) and the source of publication.

ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)

September 2023 | Vol. 15 | No. 9 | Pages: 23827–23930

Date of Publication: 26 September 2023 (Online & Print)

DOI: [10.11609/jott.2023.15.9.23837-23930](https://doi.org/10.11609/jott.2023.15.9.23837-23930)

www.threatenedtaxa.org

Article

Phylogenetic insights on the delineation of Mysore and Malabar subspecies of the Grey Slender Loris *Loris lydekkerianus* in southern India

– Vinay Teja, Shivakumara Manu, Honnavalli N. Kumara & Govindhaswamy Umapathy, Pp. 23827–23835

Communications

New localities and sexual dichromatism in Blue-green eyed Spotted Cuscus *Spilocucus wilsoni* Helgen et Flannery, 2004 (Mammalia: Marsupialia: Phalangeridae) from Biak Island, Indonesia

– Aksamina Maria Yohanita, Kanthi Arum Widayati, Tri Atmowidi, Hiroo Imai & Bambang Suryobroto, Pp. 23836–23842

Nest construction and repairing habits of Baya Weaver *Ploceus philippinus* (Aves: Passeriformes: Ploceidae) in the agricultural landscape of Villupuram District, Tamil Nadu, India

– M. Pandian, Pp. 23843–23856

A checklist of the avifauna of Samanatham tank, Madurai, Tamil Nadu, India

– H. Byju, N. Raveendran, S. Ravichandran & Reshma Vijayan, Pp. 23857–23869

Composition of avian communities in Ranjit Sagar Conservation Reserve, Punjab, India

– Onkar Singh Brarach, Sunil Kumar Saini & Jagdeep Singh, Pp. 23870–23878

Faunistic overview of the freshwater zooplankton from the urban riverine habitats of Pune, India

– Avinash Isaac Vanjare, Yugandhar Satish Shinde & Sameer Mukund Padhye, Pp. 23879–23888

Utilization of a new restoration technique for the rehabilitation of a degraded mangrove ecosystem: a case study from Koggala Lagoon, Sri Lanka

– Mahanama Gamage Greshan Dhanushka, Maduwe Guruge Manoj Prasanna, Kariyawasam Marthinna Gamage Gehan Jayasuriya & Indupa Hasindi Vitanage, Pp. 23889–23897

Diversity of powdery mildew fungi from protected areas of Jizzak region, Uzbekistan - a checklist

I.M. Mustafaev, I.Z. Ortigov, K.K. Nuraliev & D.S. Khujaqulova, Pp. 23898–23910

Notes

A case report on chronic renal disease in a captive wild Leopard *Panthera pardus* (Mammalia: Carnivora)

– Abhishek Verma, Rakesh Kumar, Smriti Jamwal, Ankita, Rajendra Damu Patil & Rajesh Kumar Asrani, Pp. 23911–23913

The first photographic evidence of Ruddy Mongoose *Herpestes smithii* Gray, 1837 (Mammalia: Carnivora: Herpestidae) in Katerniaghata Wildlife Sanctuary, Uttar Pradesh, India

– Javed Anver, Vipul Maurya & Sanjay Kumar Pathak, Pp. 23914–23916

New locality record of the Asiatic Long-tailed Climbing Mouse *Vandeleuria oleracea* (Bennett, 1832) (Mammalia: Rodentia: Muridae) from Kohora River Basin, Assam, India

– Sourav Gupta, Ramie H. Begum, Jayanta Kumar Roy, M. Firoz Ahmed & Shyamkant S. Talmale, Pp. 23917–23919

New distribution record of fish *Clarias garua* (Hamilton, 1822) (Siluriformes: Ailiidae) from the Sarpang District in southern central part of Bhutan

– Sangay Dorji & Jigme Tenzin, Pp. 23920–23924

Kukumseri: a home to *Colchicum luteum* Baker (Colchicaceae), a rare and endangered medicinal herb

– Rajender Kumar Sharma, Pp. 23925–23927

First record of the Western Himalayan Yew *Taxus contorta* (Gymnosperms: Cupressales: Taxaceae) from Lumbini Province, Nepal

– Santa Bahadur Thing, Deepak Raj Prakash Janga Shahi & Shashi Shrestha, Pp. 23928–23930

Publisher & Host

