

for conservation globally

Journal of  
Threatened  
**TAXA**



10.11609/jott.2022.14.5.20951-21126

www.threatenedtaxa.org

26 May 2022 (Online & Print)

14(5): 20951-21126

ISSN 0974-7907 (Online)

ISSN 0974-7893 (Print)

Open Access





No. 12, Thiruvannamalai Nagar, Saravanampatti - Kalapatti Road, Saravanampatti,

Coimbatore, Tamil Nadu 641035, India

Ph: +91 9385339863 | [www.threatenedtaxa.org](http://www.threatenedtaxa.org)

Email: sanjay@threatenedtaxa.org

**EDITORS****Founder & Chief Editor****Dr. Sanjay Molur**Wildlife Information Liaison Development (WILD) Society & Zoo Outreach Organization (ZOO),  
12 Thiruvannamalai Nagar, Saravanampatti, Coimbatore, Tamil Nadu 641035, India**Deputy Chief Editor****Dr. Neelesh Dahanukar**

Noida, Uttar Pradesh, India

**Managing Editor****Mr. B. Ravichandran**, WILD/ZOO, Coimbatore, 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 641035, India**Dr. B.A. Daniel**, ZOO/WILD, Coimbatore, Tamil Nadu 641035, India**Editorial Board****Dr. Russel Mittermeier**

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

**Prof. Mewa Singh Ph.D., FASc, FNA, FNAsc, FNAPsy**

Ramanna 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 Fisher**

Senior 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 &amp; Ocean Studies, Kochi, Kerala, India

**English Editors****Mrs. Mira Bhojwani**, Pune, India**Dr. Fred Pluthero**, Toronto, Canada**Mr. P. Ilangovan**, Chennai, India**Web Development****Mrs. Latha G. Ravikumar**, ZOO/WILD, Coimbatore, India**Typesetting****Mr. Arul Jagadish**, ZOO, Coimbatore, India**Mrs. Radhika**, ZOO, Coimbatore, India**Mrs. Geetha**, ZOO, Coimbatore India**Fundraising/Communications****Mrs. Payal B. Molur**, Coimbatore, India**Subject Editors 2019–2021****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**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. Ferdinando 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**, Kadoorie Farm and Botanic Garden Corporation, Hong Kong S.A.R., China**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. Manda 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. Lakshminarasimhan**, Botanical Survey of India, Howrah, India**Dr. Larry R. Nobile**, 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. Sinu**, 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. Navendu Page**, Wildlife Institute of India, Chandrabani, Dehradun, Uttarakhand, 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, Bangladesh**Mr. Jatishwar 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, IndiaFor Focus, Scope, Aims, and Policies, visit [https://threatenedtaxa.org/index.php/JoTT/aims\\_scope](https://threatenedtaxa.org/index.php/JoTT/aims_scope)For 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](https://threatenedtaxa.org/index.php/JoTT/policies_various)

continued on the back inside cover

Cover: Dorsal view of Mantis Shrimp *Cloridina ichneumon* (Fabricius, 1798) & *Gonodactylellus demaniae* (Henderson, 1893). © Fisheries Research Station, Junagadh Agricultural University, Sikka.



## Drought may severely reduce the ability of wild Asian Elephants *Elephas maximus* (Mammalia: Proboscidea: Elephantidae) to resist opportunistic infections

B.M. Chandranaik<sup>1</sup> , Vardhaman Patil<sup>2</sup> , D. Rathnamma<sup>3</sup> , G.S. Mamatha<sup>4</sup> , K.S. Umashankar<sup>5</sup> ,  
D.N. Nagaraju<sup>6</sup>  & S.M. Byregowda<sup>7</sup> 

<sup>1,7</sup> Institute of Animal Health and Veterinary Biologicals, KVAFSU, Hebbal, Bengaluru, Karnataka 560024, India.

<sup>2,3,4</sup> Veterinary College, Hebbal, Bengaluru, Karnataka 560024, India.

<sup>5</sup> Nagarahole Tiger Reserve, Hunsur, Mysore District, Karnataka 571105, India.

<sup>6</sup> Bandipur Tiger Reserve, Gundlupete, Chamarajnagara District, Karnataka, India.

<sup>1</sup>drbmchandranaik@gmail.com (corresponding author) <sup>2</sup>vd\_doc@rediffmail.com, <sup>3</sup>rathnarohit@gmail.com,

<sup>4</sup>drmamathags@gmail.com, <sup>5</sup>drumashankarvet@gmail.com, <sup>6</sup>nagarajudnvet@gmail.com, <sup>7</sup>smbyregowda@gmail.com

**Abstract:** The present study was conducted to assess the microbial quality of water in forest waterholes in different seasons and its possible impact on wild animals, at Bandipur and Nagarhole Tiger Reserve forests in the state of Karnataka, India, during the year 2012 which evidenced drought, and the year 2014 which witnessed normal rainfall in these forests. The forests recorded the death of 39 wild elephants during April and May of 2012. One ailing elephant was confirmed to have high fever, diarrhoea, leucocytosis, and symptoms of colic. Water samples collected from major waterholes during the peak drought showed higher numbers of coliforms and several species of opportunistic bacteria including species of *Vibrio* and *Campylobacter*. In the year 2014–15, with normal rainfall, the death of less than 10 wild elephants was documented during April to May, 2015. We collected water samples from 20 major waterholes every month from June 2014 to May 2015 and assessed the water quality. We found that the microbial water quality improved in rainy season (June–September), started deterioration in winter (October–January) and became poor in summer (February–May). Though, the water during the summer of 2014–15 was equally of poor microbial quality as seen during peaks of droughts, the elephant deaths were relatively lower, signifying the role of normal rainfall in forests which provides the availability of fodder and water, which determines the general body condition and ability to resist opportunistic infections. We discuss the measures suggested and implemented from this study and their utilities at ground level.

**Keywords:** *Campylobacter*, Coliforms, forest waterholes, microbial quality, rainfall, *Vibrio*, water, wildlife.

**Editor:** Heidi Riddle, Riddle's Elephant and Wildlife Sanctuary, Arkansas, USA.

**Date of publication:** 26 May 2022 (online & print)

**Citation:** Chandranaik, B.M., V. Patil, D. Rathnamma, G.S. Mamatha, K.S. Umashankar, D.N. Nagaraju & S.M. Byregowda (2022). Drought may severely reduce the ability of wild Asian Elephants *Elephas maximus* (Mammalia: Proboscidea: Elephantidae) to resist opportunistic infections. *Journal of Threatened Taxa* 14(5): 20951–20963. <https://doi.org/10.11609/jott.7835.14.5.20951-20963>

**Copyright:** © Chandranaik et al. 2022. 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:** This study was funded by Govt. of India's Centrally Sponsored Scheme-Project Elephant-2013–14 vide Govt. of Karnataka order No. PCCF(WL)/B1/CR-01/2013-14 dated 31.10.2013 for the research project 'Monitoring of quality of water at major waterholes in Bandipur and Nagarhole forest area'.

**Competing interests:** The authors declare no competing interests.

**Author details & Author contributions:** See end of this article.

**Acknowledgements:** The authors are thankful to the Ministry of Environment and Forest, Government of India, and to the Forest Department of Government of Karnataka for funding the research work. Authors are also thankful to the unconditional support of all forest officers, forest guards, jeep drivers of Bandipur and Nagarhole tiger reserves, who had to travel in the wild forest under difficult climatic conditions at different stages of this study spanning over three years.



Government Of India



Government of Karnataka



JOURNAL OF  
THREATENED  
TAXA



JOTT

## INTRODUCTION

Concern about climate change has intensified interest in understanding how climatic variability affects animal life. Despite such effects being potentially most dramatic in long-lived, slow reproducing, large terrestrial mammals, little is known of the effects of climatic variation on survival in such species. A series of complex climatic changes affecting the equatorial pacific region causes reversal of wind patterns in the Pacific Ocean and leads to consecutive droughts in Australia and Asia (Wenju et al. 2014; Chris 2015).

Water is essential for living. Wild animals depend on rainwater that accumulates in waterholes in forests. The rainwater that accumulates in waterholes remains throughout the year and is prone to microbial contaminations arising out of various sources, of which faecal contaminations from humans and wild animals are most important (Obi et al. 2002). Unpredictable chronic droughts lead to acute shortage of drinking water, forcing wild animals either to depend on limited water available in waterholes or they get no water at all (Durham et al. 2008). It has been extensively studied and reported that the microbial diarrhoeal diseases are a major public health problem from ingestion of water contaminated with human and /or animal faeces (Seas et al. 2000; Cabral 2010). However, no studies have been undertaken to correlate wild animal mortality with droughts and water quality in the wild.

The present study attempts to assess possible factors contributing to the deterioration of microbial quality of water during different seasons of a year, and its possible impact on wild animals. We used elephant mortality as evidence to compare the water quality and its impact during chronic droughts, in comparison to seasons of normal rainfall (Figure 2). Though microbial quality is not the only reason for animal deaths, this study analyses how the microbial quality of water in waterholes in forests could predispose elephants to mortality during extended droughts. This study was carried out in the Bandipur Tiger Reserve (also known as Bandipur National Park) and Nagarhole Tiger Reserve (also known as Nagarhole/Rajiv Gandhi National Park) forests in the state of Karnataka, India, during 2012 which witnessed severe drought in these forests, and in the year 2014–15 which had normal rainfall. The study is of significance since recurrent droughts could be a common feature in times to come, owing to severely disrupted global weather patterns and we need to know its impact on wildlife.

## MATERIALS AND METHODS

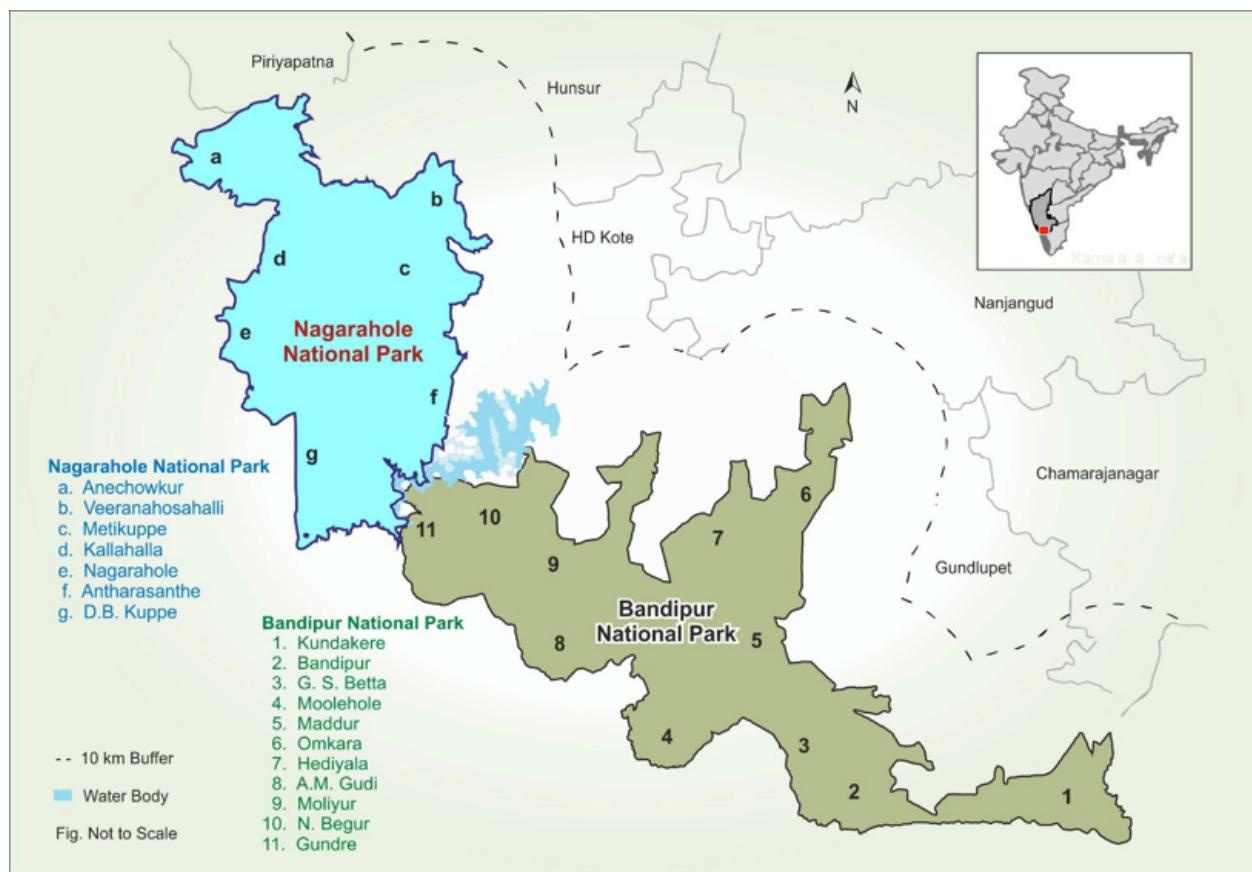
### Study area

The Bandipur Tiger Reserve with an area of 874.20 km<sup>2</sup> and the Nagarhole Tiger Reserve with an area of 643 km<sup>2</sup>, are important components of the 5,500 km<sup>2</sup> 'Nilgiri Biosphere Reserve' which is one of the largest conservation areas in the world (Chandranaike et al. 2016, 2017) (Figure 1). The forests are a large chunk of dry deciduous forest which receives heavy pre-monsoon showers in late May. The south-west monsoon starts by mid-June and lasts until September. These two forests are one of the richest wildlife areas in India, being noted for their assemblage of seven large ungulate species—Muntjac *Muntiacus muntjak*, Chital *Axis axis*, Sambar *Rusa unicolor*, Chousingha *Tetracerus quadricornis*, Gaur *Bos gaurus*, Wild Pig *Sus scrofa cristatus*, & Asian Elephant *Elephas maximus* and three major carnivores—Tiger *Panthera tigris*, Leopard *Panthera pardus*, & Dhole *Cuon alpinus*. The forest supports a high ratio of predator and prey species. As per the 2012 elephant census, Bandipur forest has a population of 1,697 elephants and Nagarhole forest has 1,320 elephants, constituting 27.9 % and 21.8 % of the total 6,072 elephants in Karnataka state, respectively (Varma & Sukumar 2012).

Ten major waterholes each in Bandipur forest and Nagarhole forest were selected for the purpose of monitoring the quality of water during this study period. Ten major waterholes selected in Bandipur forest included; Moolapurakere (Range: Bandipur), Kharapurakere (Range: Kundkere), Tavarekattekere (Range: Bandipur), Hirikere (Range: G.S. Betta), Natkalkere (Range: Maddur), Madrakatte (Range: Moolehole), Nataraja Kolachi (Range: A.M. Gudi), Hidgalpanchi (Range: Muliur), Chikkamauthige Kolachi (Range: N. Begur), and South Kere (Range: Omkar)

Ten major waterholes selected in Nagarhole forest for the purpose of monitoring the quality of water included; Kambapurakere (Range: Anechoukur), Maralakandakere (Range: Anechoukur), Kallahalla (Range: Kallahalla), Doddahallakere (Range: Nagarhole), Marappanakere (Range: Nagarahloe), Bisilawadikere (Range: Antharasanthe), Bidirukattekere (Range: Veeranahosahalli), Rajegowdanakatte (Range: Veeranahosahalli), Holerahundikere (Range: Metikuppe), and Seegurukere (Range: D.B. Kuppe).

For the purpose of this study we have considered the months from June to September as rainy season; October to January as winter season, and February to May as summer season.



**Figure 1. Map of the study areas.**

### Sample Collections

#### i) During droughts of 2012

Clinical samples from ailing and dead elephants.

Thirty-nine wild elephants died during the months of April–May, 2012. An ailing elephant was examined on the banks of the dried-up Kabini River in Bandipur forest and blood samples were collected for laboratory examination. The elephant was treated symptomatically with fluids and antibiotics but the animal did not survive. Post-mortem examination was conducted on the fresh elephant carcass.

In most other cases of elephant deaths it was very difficult to get fresh carcasses for post-mortem examination and hence, alternatively, bone marrow samples from femur bones were aseptically collected from 12 near putrefied elephant carcasses in Bandipur and Nagarhole forests during April–May, 2012.

#### Water samples

Water samples from the waterholes were aseptically collected during April–May, 2012, as per the procedure described previously (Obi et al. 2002) and transported on ice to the Institute of Animal Health and Veterinary

Biologicals, Bengaluru, India, for microbiological and parasitological investigations.

#### ii) During normal rain fall year of 2014–15

Water samples were collected from each of the above 20 major waterholes every month, starting from June 2014 (beginning of rainy season) to May 2015 (end of the summer season) for microbial and parasitological analysis. Samples were collected as described previously and transported to laboratory under cold chain conditions.

### Microbiological Analysis

(i) Water samples: Microbiological analysis of water samples were performed as described previously (Standard Methods 1998; Nevodo & Cloete 1999; Obi et al. 2002; Quinn et al. 2011). Briefly, for heterotrophic bacteria, the spread-plate method was done on nutrient agar and plates were incubated at 37 °C for 48 hours. The total Coli forms and *E. coli* counts were enumerated using USFDA and WHO approved petri-films procured from 3M Company, USA, as per previously described methods (Jordano et al. 1995). All the bacteria that were

isolated under the present study were confirmed by specific biochemical tests as prescribed previously (Obi et al. 2002; Quinn et al. 2011).

(ii) Organ samples: Blood samples collected from an ailing elephant, organ samples collected at post-mortem, and bone marrow samples collected from putrefied carcasses were subject to microbiological culture as per previously described procedures (Quinn et al. 2011; Chandranaike et al. 2015, 2016).

### Parasitological quality assessment

Presence of parasitic worms and/or their eggs in water samples was done by floatation and sedimentation techniques as previously described by Soulsby (1982).

### Polymerase Chain reaction

For DNA extraction, five milliliters of nutrient broth inoculated with bacteria from a single colony of the isolate, and culture was incubated overnight with shaking. Bacterial cells were harvested by centrifugation at 1,000 X g for 15 min. Genomic DNA was extracted from the disrupted cells using DNA extraction kit procured from Amnion Biotech Pvt. Ltd. Bengaluru, Karnataka, India, following the protocols provided by the manufacturer. The previously described primers and the protocols were used for PCR confirmation of *Escherichia*, *Campylobacter*, and *Vibrio* species (Holland et al. 2000; Soren & Katharina 2005; Cheryl et al. 2007).

## RESULTS

### Drought of 2012

Out of 20 major waterholes in forest area under the study, nine had dried up by April–May of 2012 (3b,c in Image 1). The other eleven waterholes under the study had very little water, which appeared muddy, greenish, with heaps of dried-up as well as fresh elephant dung (Supplementary Image 1). It is important to note that these two forests received less than the normal rainfall in the year 2011 (Figure 2), and the drought of 2012 was an extended period of dry spell (Figure 2). Water samples collected in all the waterholes had high microbial contamination with an average total coli form counts of  $6.7 \times 10^5$  cfu/ml, mean total *E. coli* counts of  $9.2 \times 10^3$  cfu/ml (Table 1). On petri films, the coli formed red colonies and *E. coli* formed blue colonies (Supplementary). The water samples collected from the 11 waterholes which contained water at the time of collection during April–May, 2012, yielded growth of *Vibrio cholerae*, *V. parahaemolyticus*, and species of *Salmonella*, *Klebsiella*,

*Shigella*, *Staphylococcus*, *Streptococcus*, *Bacillus*, and *Campylobacter* (Supplementary Image 3). These bacterial isolates were confirmed by biochemical tests, viz., Indole, citrate, catalase, nitrate, urease, oxidase, methyl red, voges-prausker, ornithine-decarboxylase, nitrate reduction, lysine decarboxylase and arginine hydrolase test. *Escherichia*, *Vibrio*, and *Campylobacter* were additionally confirmed by polymerase chain reaction.

The water samples contained eggs of gastrointestinal parasites of Strongyles, Amphistomes and *Fasciola* flukes (A, B, C in Supplementary Image 4). During the drought, the forests witnessed recurrent massive forest fires (Supplementary Image 5) destroying minimally available fodder to larger mammals, and killing several smaller wild animals which could not escape the raging forest fire.

The ailing elephant that was examined on the banks of Kabini River at the peak of drought conditions had a high fever of 104 °F. Blood samples revealed elevated liver enzyme SGOT at 219 IU/μl (Normal value: 5–55 IU/μl), total leukocyte counts at 18,000/μl (Normal value: less than 12, 000/μl) (Miller & Fowler 2012). The ailing elephant finally succumbed to acute colic symptoms. Post mortem revealed lesions of severe enteritis, empty bowels, heavy worm loads (Image 2), and hepatitis. Out of 12 bone marrow samples collected from elephant carcasses in late decomposition, nine yielded growth of mixed cultures of *E. coli*, *Salmonella* sp., *Shigella* sp., and *Klebsiella* sp. The study recorded death of 39 elephants during April–May, 2012.

### Normal rainfall year of 2014–15

During this study, it was observed that the quantity of water in waterholes started increasing from June through the rainy season in August and reached the maximum levels by November. The water level started depleting from December and reached minimum levels by April to mid-May (1a,b,c in Image 1). Total coli form counts and *E. coli* counts were lowest during rainy season which gradually increased during late winter and the counts reached highest number during summer months (Table 1). Water samples collected during the months of June, July, August, September, October, November, and December yielded growth of *Escherichia*, *Aeromonas*, *Pseudomonas*, *Staphylococcus*, *Salmonella*, *Streptococcus*, *Bacillus*, *Klebsiella*, and *Shigella* bacterial species. Water samples collected during January, March, April, and May in addition to the above bacterial species yielded growth of *Vibrio cholerae*, *V. haemolyticus*, and species of *Campylobacter* (Table 2)

**Table 1. Bacterial counts observed during different seasons in major waterholes of Bandipur and Nagarhole Tiger Reserve forests.**

Parameter	During normal rainfall year of 2014–15			During the drought year 2012
	Rainy season	Winter season	Summer season	April and May, 2012
Coli form count	Mean: $2.4 \times 10^2$ S.D: $2.1 \times 10^2$	Mean: $1.8 \times 10^3$ S.D: $2.45 \times 10^2$	Mean: $4.3 \times 10^5$ S.D: $3.2 \times 10^5$	Mean: $6.7 \times 10^5$ S.D: $4.2 \times 10^5$
<i>E.coli</i> count	Mean: $3.7 \times 10^2$ SD: $3.1 \times 10^1$	Mean: $2.7 \times 10^2$ SD: $2.7 \times 10^2$	Mean: $6.2 \times 10^3$ SD: $4.2 \times 10^3$	Mean: $9.2 \times 10^3$ SD: $5.1 \times 10^3$

**Image 1. Water levels in waterholes: 1a, 2a, 3a—Completely filled up waterholes in rainy season | 1b, 2b, 3b—Waterholes in winter | 1c, 2c, 3c—Dried up waterholes in summer. © Authors.**

Water samples collected during all the months (June 2014–May 2015) revealed the presence of eggs of *Fasciola*, *Amphistomes*, *Strongyles*, *Taenia* and *Coccidian* oocysts (Table 2). The study found that the habit of wild animals to defecate while consuming water (as observed in several instances during this study while collecting water samples) had possibly resulted in an abundance of faecal droppings in the water holes, especially at the fringes of the waterholes where they stand and drink water (D, E, F, G in Supplementary Image 4). Abundant numbers of different types of snails which act as intermediate hosts for trematode flukes (*Fasciola* and *Amphistomes*) were observed near the waterholes (H, I,

in Supplementary Image 4). The monthly average rainfall data in the study area during 2011, 2012, and 2014 is depicted in Figure 2. Forests witnessed the death of less than 10 elephants in April–May, 2015.

## DISCUSSION

Bandipur and Nagarhole Tiger Reserves witnessed an extended drought during 2012. Most of the findings that are described in this study are the first time reports in elephants; hence, we have discussed our results in comparisons with available reports in domestic animals

and humans.

### Drought of 2012

The major waterholes had either completely dried up or were left with little water which was highly contaminated. There was an acute shortage of fodder to elephants as the green vegetation had dried-up in the forest. Also, the dried-up grass, shrubs, and trees had been destroyed by recurrent forest fires. These factors lead the elephants to chronic starvation and dehydration; gradually contributing to poor nutrition, poor body condition, and consequent immunosuppression.

In the absence of any other water sources, elephants had to drink the contaminated water available in the waterholes, which were the source of heavy loads of different types of opportunistic pathogens especially the *coli* forms. Under natural conditions when the elephants are healthy with good nutrition and immunity, they can withstand most opportunistic pathogens including coliforms and the gastrointestinal parasitic infestations (Quinn et al. 2011; Miller & Fowler 2012). However, under severe drought conditions, the immune compromised wild animals are susceptible to opportunistic and/or acute bacterial infections/septicemia (Quinn et al. 2011; Chandranaike et al. 2015) which cause high fever, hepatitis, pancreatitis, acute enteritis, dehydration, and other systemic disorders. Hepatitis, pancreatitis, and enteritis are highly painful conditions which cause colic and struggling, as observed in most of the elephant deaths in the present investigation.

Potential pathogenic and/or opportunistic bacterial species of *Escherichia*, *Vibrio*, *Aeromonas*, *Shigella*, *Klebsiella*, *Salmonella*, *Bacillus*, *Pseudomonas*, and *Campylobacter* were isolated from all the water sources studied during drought. The presence of these bacteria in water sources is in agreement with previous reports (Cabral 2010). These enteric bacteria have been reported to act as the causative agents of various diseases and their complications such as diarrhoea/dysentery, septicaemia, dehydration, hypovolaemic shock, acidosis, and haemo-concentration (Ongunsanya et al. 1994; Seas et al. 2000; Cabral 2010).

*Vibrio cholerae* can grow at 40°C with pH 9–10. The growth is stimulated by the presence of sodium chloride which is available as a result of rapid evaporation of water in waterholes due to heat of the summer. There are more than 200 serovars of *V. cholera*, characterized based on the structure of the lipopolysaccharide. Only two serovarieties named O1 and O139 are involved in causing true cholera. However, other serovarieties can cause gastroenteritis, but not cholera. The severity of

**Table 2. Bacterial isolates and parasitic eggs/cysts recovered from the water samples collected during this study.**

<i>Escherichia</i> spp.	
<i>Vibrio</i> spp.	
<i>Salmonella</i> spp.	
<i>Klebsiella</i> spp.	
<i>Campylobacter</i> spp.	
<i>Pseudomonas</i> spp.	
<i>Streptococcus</i> spp.	
<i>Staphylococcus</i> spp.	
<i>Shigella</i> spp.	
<i>Bacillus</i> spp.	
<i>Aeromonas</i> spp.	
Fasciola	
Amphistomes	
Strongyles	
Taenia	
Coccidia	



**Image 2. Post mortem lesions in elephants died during drought: A—Lesions of severe enteritis | B, C—Heavy helminth worm load.**

the disease depends on several factors, and importantly on the individual's immunity and the inoculum (Sack et al. 2004; Todar 2009). *Vibrio parahaemolyticus* is a well-documented causal agent of acute food-borne gastroenteritis (Sack et al. 2004; Quinn et al. 2011).

The principal habitat of *Salmonella* is the intestinal tract of humans and animals including wild animals. Food-borne *Salmonella* gastroenteritis is frequently caused by ubiquitous *Salmonella* serovars (Quinn et al. 2011). *Shigella* is typically an inhabitant of the intestinal tract of humans and other primates. It is primarily spread by fecal-contaminated drinking water causing bacillary dysentery (Kapperud et al. 1995; Farque et al. 2002; Tetteh & Beuchat 2003).

*E. coli* strains have been grouped into several groups of which enterotoxigenic, enterohemorrhagic and enteroinvasive (Cabral 2010; Quinn et al. 2011) serotypes are of significant importance and can be transmitted through contaminated water. Disease caused by *E. coli* follows ingestion of contaminated food or water and is characterized by acute abdominal pain, profuse watery diarrhoea lasting for several days that often leads to dehydration. Outbreaks involving consumption of drinking water contaminated with human sewage or cattle feces have been documented in human dwellings. An increasing number of outbreaks are associated with the consumption of fruits and vegetables (e.g., sprouts, lettuce) contaminated with feces from domestic or wild animals at some stage of growth. EHEC has also been isolated from water bodies (ponds, streams), wells and water troughs, and has been found to survive for months in manure and water-trough sediments (Scheutz & Strockbine 2005).

Possible sources of contamination of the water bodies in forests include animal faeces or introduction of micro-organisms by birds and insects (Paul et al. 1995; Nevodo & Cloete 1999; Obi et al. 2002; Cabral 2010). Higher bacterial levels could also be due to heightened ecological activities (Strockbine & Maurelli 2005). The habits of wild animals to defecate and urinate in the waterholes as they drink water could be important sources of faecal contamination with coli forms, the parasitic eggs and other opportunistic pathogens isolated during this study. The flow of water into waterholes from adjacent (surrounding) villages with human habitations where open defecation is practiced by their populace could also be another significant source of coli forms and parasitic eggs/cysts noticed in the waterholes. It should, however, be noted that the presence of faecal coli forms in the water sources may not be definitive for a faecal origin of the bacteria (Paul

et al. 1995). Investigators have reported the presence of faecal coli forms in tropical environments in the absence of any source of fecal contamination (Hardina & Fujioka 1991; Palupi et al. 1995; Hazen 1998; Fernandez et al. 2000).

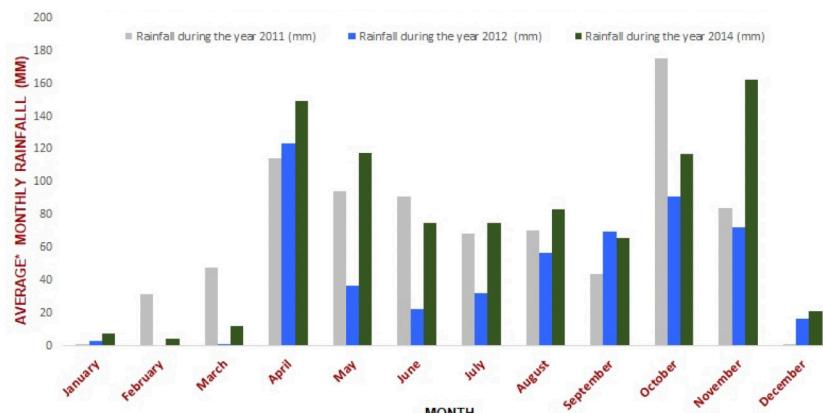
Snails act as intermediate hosts for *Fasciola* and *Amphistome* trematodes (Soulsby 1982), the presence of abundant snails of different species on the shores of waterholes could be a prominent reason for detection of fluke eggs in water samples.

These two forest areas had received lower than normal rains in the year 2011, and the situation worsened in 2012 leading to severe drought conditions (Figure 2). Possibly, as a consequence of all these factors, 39 elephants died during April–May, 2012 in these two forest areas. Most of the elephants had died with symptoms of colic as observed by severe struggling of the animals before death. The blood picture of leucocytosis indicated bacterial infection, and increased liver enzymes indicated toxic changes. The post-mortem examination revealed lesions of severe inflammation of intestines and septicaemic changes in an elephant that was examined on the banks of Kabini River during the peak of drought in 2012. Further, the bone marrow samples of the elephants that died during droughts yielded growth of *E. coli* and other coli forms and these opportunistic pathogens have been reported to be aetiologies for severe enteritis and septicaemia in immunosuppressed animals (Quinn et al. 2011). The post-mortem also revealed the presence of heavy loads of parasites in the gastro-intestinal tract, which correlates with the current findings of parasitic eggs in water samples.

#### Normal rainfall of 2014–15

After good pre-monsoon and monsoon rains, all the waterholes were full to their brim by November. The quantity of water gradually decreased from the month of December, reached the lowest in the summer months of March, April, and May. Even when the rainfall is normal, the water in waterholes continue to be the source of opportunistic pathogens and various species of gastrointestinal parasites as evidenced by growth of coliforms and presence of eggs /ova in water.

During 2014–15, the forests received normal rainfall but the bacterial counts were very high during the summer season (March–April, 2015) which was almost similar to the counts recorded during the drought conditions of 2012. However, the death of less than ten elephants was noted in April–May, 2015. The normal monsoon rains of 2014–15 had possibly resulted in



\* Average of rainfall recorded in rain gauges at Bandipur (Rain gauge code: 80201); Begur (Rain gauge code: 80202); Gundlupete (Rain gauge code: 80203); Hunsur (Rain gauge code: 220202) during the year 2011, 2012 and 2014

Figure 2. Average monthly rainfall in the study area during the years 2011, 2012, and 2014.



Image 3. Measures suggested from the findings of this study and their implementation: A—Construction of smaller artificial water tanks and fill them with water tankers | B—Removing obstructing bigger shrubs surrounding major waterholes before every rainy season so that more and more water gets accumulated in waterholes | C—Installation of solar powered pumping bore wells near major waterholes at feasible locations in the forest.

sufficient availability of fodder for animals keeping them in good body condition and relatively better immunity, which possibly gave them the ability to resist infections caused by opportunistic pathogens present in the water they consume.

The study records that rainfall directly controls the availability of feed and water in forests; and availability of feed and water determines the general body condition of wild animals and their ability to resist infections. During droughts there is an acute shortage of feed and water leading to poor body condition with total immunosuppression; possibly making them susceptible for opportunistic pathogens present in water they consume leading to colic, diarrhoea, dehydration, septicemia, and death.

El Nino events are a prominent feature of climate variability with global climatic impacts, severely disrupted global weather patterns, affecting ecosystems agriculture, tropical cyclones, drought, bushfires, floods, and other extreme weather events worldwide. Here we present evidence of such changing climate on the survivability of wildlife. Increasing temperatures, combined with changes in rainfall and humidity, may have significant impacts on wildlife, domestic animals, and human health. When combined with expanding human population, these changes could increase demand on limited water resources, leading to more habitat destruction, and provide yet more opportunities for infectious diseases (Hofmeister et al. 2012) and the elimination of wildlife species (McLean 2016). Droughts of the future are likely to be more frequent, severe, and longer lasting than they have been in recent decades (Toby 2020). Through this present study we have attempted to give a glimpse of the future of wildlife in events such as drastic climatic changes.

## MANAGEMENT IMPLICATIONS

### Measures suggested from the findings of this study and impact of their implementation

1. The study found that the growth of heavy shrubs in and around major waterholes had prevented the flow of water into waterholes. It was suggested to take measures to clear these shrubs before every rainy season so that more water accumulates in waterholes.

2. In absence of water in major waterholes during drought conditions, it was suggested to take measures to provide water in a few major waterholes through water tankers.

3. To help smaller animals in the forest it was suggested to construct small artificial water tanks and fill them with water.

4. It was suggested to install solar powered pumping bore wells at feasible locations in the forest.

All the suggested measures have been implemented (Image 3) at most major waterholes by the Government of Karnataka, possibly helping many wildlife species during summer and drought situations at Bandipur and Nagarhole Tiger Reserves in recent years.

## REFERENCES

**Cabral, J.P.S. (2010).** Water Microbiology: Bacterial Pathogens and Water. *International Journal of Environment Research and Public Health* 7: 3657–3703

**Chandranaike, B.M., B.P. Shivashankar, P. Giridhar & D.N. Nagaraju (2016).** Molecular characterisation and serotyping of *Pasteurella multocida* isolates from Asiatic Elephants (*Elephas maximus*). *European Journal of Wildlife Research* 62: 681–685

**Chandranaike, B.M., R. Hegde, B.P. Shivashankar, P. Giridhar, H.K. Muniyellappa, R.S. Kalige, B.R. Sumathi, K. Nithinprabhu, N. Chandrashekhar, V. Manjunatha, J. Nirupama, A. Mayanna, G.K. Chandrakala, S. Kanaka & M.D. Venkatesha (2015).** Serotyping of Foot and Mouth Disease virus and *Pasteurella multocida* isolates from Indian Gaurs (*Bos gaurus*) concurrently infected with foot and mouth disease and haemorrhagic septicæmia. *Tropical Animal Health and Production* 47: 933–93

**Chandranaike, B.M., B.P. Shivashankar, K.S. Umashankar, P. Giridhar, S.M. Byregowda & B.M. Shrinivasa (2017).** *Mycobacterium tuberculosis* infection in free-roaming wild Asian Elephant. *Emerging Infectious Diseases* 23: 555–557.

**Cheryl, L.T., S.P. Jayna, D.P. Nancy, G.S. Evangeline, A.B. Cheryl & A.S. Nancy (2007).** Identification of *Vibrio* isolates by a Multiplex PCR Assay and *rpoB* Sequence Determination. *Journal of Clinical Microbiology* 45: 134–140.

**Chris, C. (2015).** Developing El Nino could be strongest on record: Event could bring rain to drought-stricken California and dry conditions to Australia. *Nature* 2015: 1–2. <https://doi.org/10.1038/nature.2015.18148>

**Faruque, S.M., R. Khan, M. Kamruzzman, S. Yamasaki, Q.S. Ahmad, T. Azim, G.B. Nair, Y. Takeda & D.A. Sack (2002).** Isolation of *Shigella dysenteriae* type 1 and *S. flexneri* strains from surface waters in Bangladesh: comparative molecular analysis of environmental *Shigella* isolates versus clinical strains. *Applied Environmental Microbiology* 68: 3908–3913

**Fernandez, M.C., N. Beatriz, S.B. Giampaolo, M. Ibanez, V. Guagliardo, M.M. Esnaola, L. Conca, P. Valdivia, S.M. Stagnaro, C. Chiale & H. Frade (2000).** *Aeromonas Hydrophila* and its relation with drinking water indicators of microbiological quality in Argentina. *Genetica* 108: 35–40.

**Hazen, T.C. (1998).** Faecal coliforms as indicators in tropical waters: a review. *Toxicological Assessment* 3: 461–477.

**Hofmeister, E., M. Rogall, K. Wesenberg, R. Abbott, T. Work, K. Schuler, J. Sleeman & J. Winton (2012).** Climate change and wildlife health: direct and indirect effects. U.S. Geological Survey Fact Sheet 2010: 3017–3021.

**Holland, J.L., L. Louie, A.E. Simor & M. Louie (2000).** PCR detection of *Escherichia coli* O157:H7 directly from stools: evaluation of commercial extraction methods for purifying faecal DNA. *Clinical Microbiology* 38: 4108–4113

**Jordano, R., C. Lopez, V. Rodriguez, G. Cordoba, L.M. Medina & Barrios (1995).** Comparison of Petri film method to conventional methods for enumerating aerobic bacteria, coliforms, *Escherichia coli* and yeast and molds in foods. *Acta Microbiology Immunology Hungaria* 42: 255–259

**Kapperud, G., L.M. Rorvik, V. Hasseltvedt, E.A. Hoiby, B.G. Iversen, K. Staveland, G. Johnsen, J. Leitao, H. Herikstad, Y. Andersson, G. Langeland, B. Gondrosen & J. Lassen (1995).** Outbreak of *Shigella sonnei* infection traced to imported iceberg lettuce. *Journal of Clinical Microbiology* 33: 609–614

**McLean, L. (2016).** Why El Niño may have contributed to mass death of seabirds. The Associated Press, New York, USA.

**Miller, R. & M. Fowler (2012).** *Fowler's Zoo and Wild Animal Medicine*. Elsevier publications, 792 pp.

**Nevondo, T.S. & T.E. Cloete (1999).** Bacterial and chemical quality of water supply in the Dertig village settlement. *Water SA* 25: 215–220

**Obi, C.L., N. Potgieter, P.O. Bessong & G. Matsaung (2002).** Assessment of the microbial quality of river water sources in rural Venda communities in South Africa. *Water SA* 28: 287–292.

**Ogunsanya, T.I., V.O. Rotimi & Adenuga (1994).** A study of the etiological agents of childhood diarrhoea in Lagos, Nigeria. *Journal of Medical Microbiology* 40: 10–14

**Palupi, K., S. Sumengen, S. Inswiarsi, L. Augustina, S.A. Nunik, W. Sunarya & A. Quraisyin (1995).** River water quality study in the vicinity of Jakarta. *Water Science and Technology* 39: 17–25

**Paul, J.H., J.B. Rose, S. Jiang, C. Kellogg & E. Shinn (1995).** Occurrence of faecal indicator bacteria in surface water and the subsurface equiter in Key Largo, Florida. *Applied Environmental Microbiology* 61: 2235–2241

**Quinn, P. J., B.K. Markey, F.C. Leonard, E.S. Fitzpatrick, S. Fanning & P.J. Hartigan (2011).** *Veterinary Microbiology and Microbial Diseases*, 2<sup>nd</sup> Edition. Wiley-Blackwell Publications, United Kingdom, 912 pp.

**Sack, D.A., R.B. Sack, G.B. Nair & A. K. Siddique (2004).** Cholera. *Lancet* 363: 223–233.

**Scheutz, F. & N.A. Strockbine (2005).** Genus *Escherichia*, pp. 607–623. In: Brenner, D.J., Krieg, N.R., Staley, J.T., (eds). *Bergey's Manual of Systematic Bacteriology*, 2<sup>nd</sup> ed. Springer, New York, USA, 949 pp.

**Seas, C., M. Alarcon, J.C. Aragon, S. Beneit, M. Quiñonez, H. Guerra & E. Gotuzzo (2000).** Surveillance of bacterial pathogens associated with acute diarrhea in Lima, Peru. *International Journal of Infectious Diseases* 4: 96–99

**Soren, P. & E.P. Katharina (2005).** Multiplex PCR for identification of *Campylobacter coli* and *Campylobacter jejuni* from pure cultures and directly on stool samples. *Olsen Journal of Medical Microbiology* 54: 1043–1047

**Soulsby, E.J.L. (1982).** *Text Book of Helminths, Arthropods and Protozoa of Domesticated Animals*. 7<sup>th</sup> Edition. Philadelphia, 809 pp.

**Standard Methods (1998).** *Standard Methods for the Examination of Water and Wastewater* (20<sup>th</sup> Edition). American Public Health Association, Washington DC, 2671 pp.

**Strockbine, N.A. & A.T. Maurelli (2005).** Genus *Shigella*. In: Bergey's Manual of Systematic Bacteriology, 2<sup>nd</sup> edn.

**Tetteh, G.L. & L.R. Beuchat (2003).** Survival, growth, and inactivation

of acid-stressed *Shigella flexneri* as affected by pH and temperature. *International Journal of Food Microbiology* 87: 131–138

**Toby, R.A. (2020).** On the essentials of drought in a changing climate. *Science* 368: 256–260.

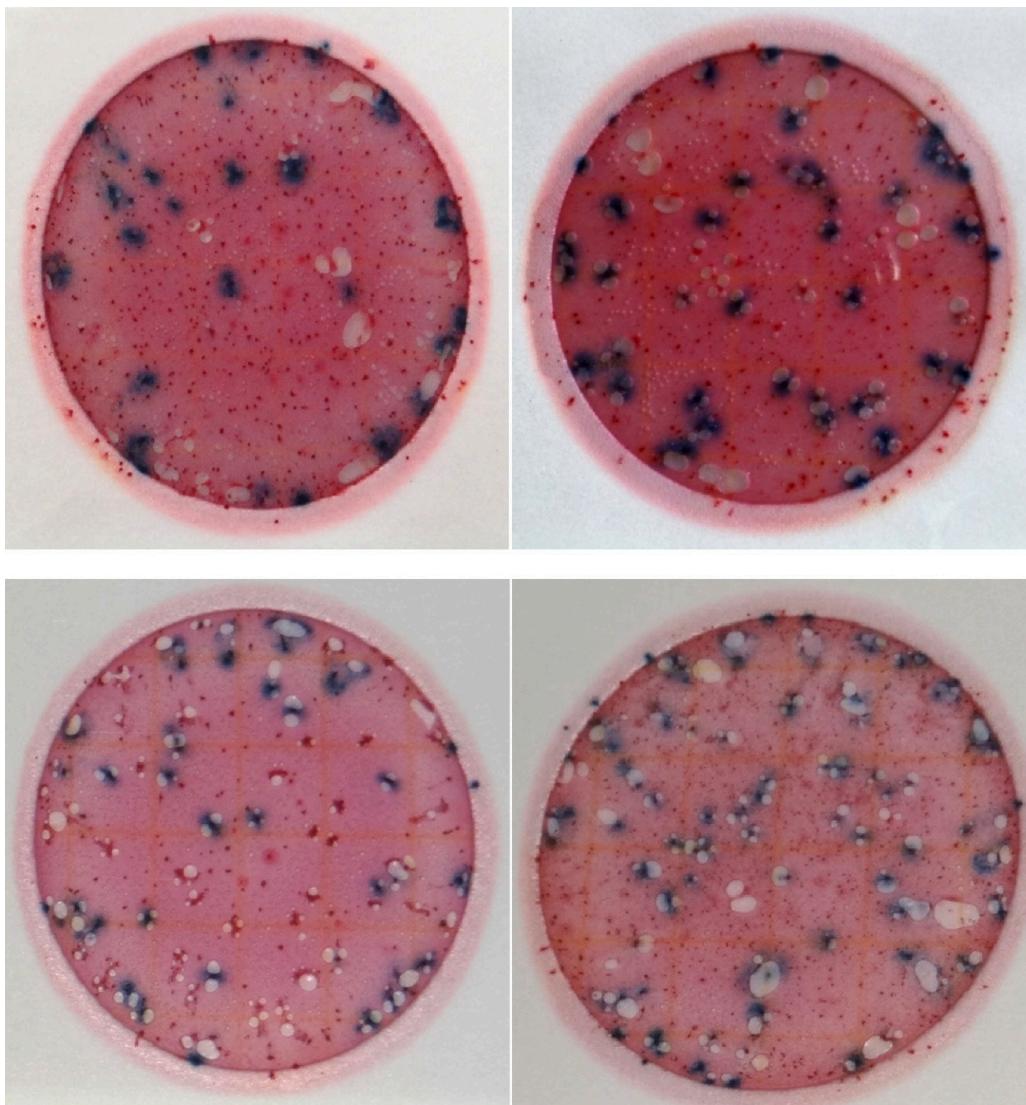
**Todar, K. (2009).** *Vibrio cholera* and Asiatic cholera, pp. 1–4. In: Todar's Online Textbook of Bacteriology. <http://www.textbookofbacteriology.net/cholera>.

**Varma, S. & R. Sukumar (2012).** Synchronized population estimation of the Asian Elephants in forest divisions of Karnataka. Dissertation, Indian Institute of Science, India.

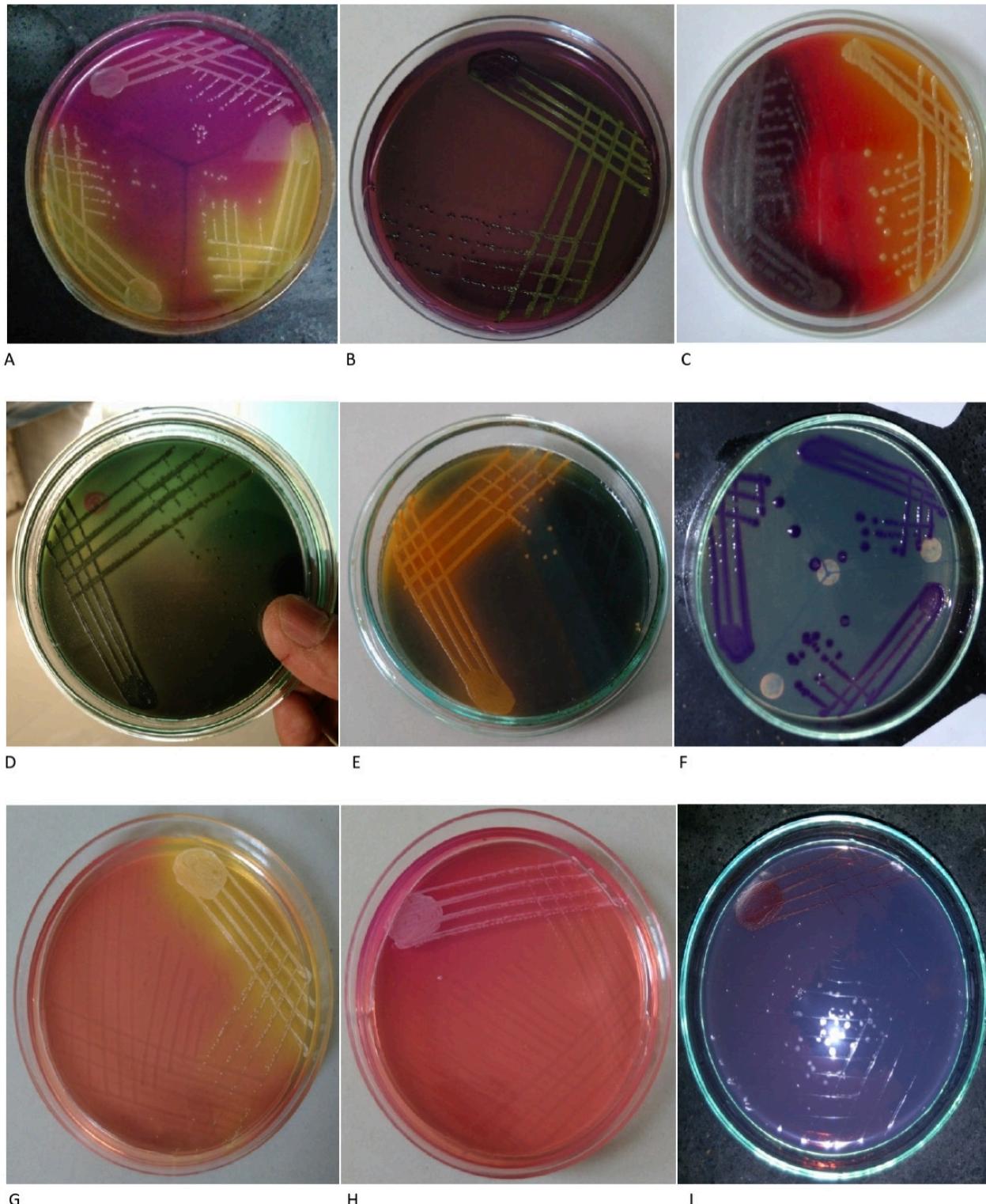
**Wenju, C., B. Borlace, L. Matthieu, V.R. Peter, C. Mat, V. Gabriel, T. Axel, S. Agus, M. Michael, L. Wu, H.E. Matthew, W. Guojian, E. Guilyardi G & J. Fei-Fei (2014).** Increasing frequency of extreme El Nino events due to greenhouse warming. *Nature Climate Change* 4: 111–116



**Supplementary Image 1.** The water in waterholes during drought appeared greenish with heaps of elephant dung at periphery.



**Supplementary Image 2.** Colonies of *coli* forms and *E. coli* on the petri films.



**Supplementary Image 3. Growth of opportunistic pathogens from water samples:** A—colonies of *Aeromonas* (yellow) and *Pseudomonas* (white) on *Aeromonas-Pseudomonas* agar | B—*E. coli* on EMB agar | C—*Salmonella E. coli* on XLD agar | D—*Vibrio parahaemolyticus* on TCBS agar | E—*Vibrio cholera* on TCBS agar | F—*Klebsiella* species on *Klebsiella* agar | G—*Staphylococcus aureus* on MSA agar | H—*Staphylococcus intermedius* on MSA agar | I—*Streptococcus* species on KF Streptococcal agar.



**Supplementary Image 4.** Eggs of gastro intestinal parasites in water samples: A—Strongyle egg | B—Amphistome egg | C—Fasciola egg | D, E, F, G—Dung in the water in the waterholes | E, F—Different species of snails observed in and around the waterholes.



**Supplementary Image 5. The forest witnessed massive forest fires during the drought.**

**Author details:** B.M. CHANDRANAIK is a Veterinarian working as a Scientist at Institute of Animal Health and Veterinary Biologicals, Hebbal, Bangalore from past 20 years, with research interests on epidemiology of zoonotic and infectious pathogens of domestic and wild animals. VARDHAMAN PATIL is a Veterinarian working for Govt. of Karnataka, he worked on this project as part of his MSc in Veterinary Microbiology at Veterinary College, Bangalore. D. RATHNAMMA is the Professor and Head of Dept. of Veterinary Microbiology, Veterinary College, Bangalore with an experience of over 25 years in teaching and research on infectious diseases of animals. G.S. MAMATHA is an Assistant Professor of Veterinary Parasitology, Veterinary College, Bangalore with an experience of over 15 years in teaching, research and extension activities. K.S. UMASHANKAR is a Veterinarian working for Govt. of Karnataka with expertise in management of wildlife diseases with over 25 years of experience in treating diseases of wild animals. D.N. NAGARAJU is a Veterinarian working for Govt. of Karnataka with over 25 years of experience in treatment and management of diseases of wild animals. S.M. BYREGOWDA is the Director of Institute of Animal Health and Veterinary Biologicals, Hebbal, Bangalore with experience and expertise of over 35 years in infectious diseases of animals and vaccine development.

**Author contributions:** BMC conceptualised the study, obtained the funding, designed the experiments, collected samples, conducted experiments, analysed and interpreted the data; VP collected the samples and conducted bacteriological analysis on the water samples; DR conducted bacteriological analysis on the water samples and interpreted the data; GSM conducted parasitological examination on the water samples and interpreted the data; KSU and DNN treated ailing animals and collected samples for this study; SMB contributed in analysis and data interpretations.





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. Lionel 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. Kuri 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  
Daniel Whitmore, State Museum of Natural History Stuttgart, Rosenstein, Germany.  
Dr. Yu-Feng Hsu, National Taiwan Normal University, Taipei City, Taiwan  
Dr. Keith W. 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

#### 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

#### 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. M. Zafar-ul Islam, Prince Saud Al Faisal Wildlife Research Center, Taif, Saudi Arabia

#### 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 2019–2021

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,  
No. 12, Thiruvannamalai Nagar, Saravanampatti - Kalapatti Road,  
Saravanampatti, Coimbatore, Tamil Nadu 641035, India  
ravi@threatenedtaxa.org

**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



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](http://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.

[www.threatenedtaxa.org](http://www.threatenedtaxa.org)

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

May 2022 | Vol. 14 | No. 5 | Pages: 20951–21126

Date of Publication: 26 May 2022 (Online & Print)

DOI: 10.11609/jott.2022.14.5.20951-21126

## Communications

### Drought may severely reduce the ability of wild Asian Elephants *Elephas maximus* (Mammalia: Proboscidea: Elephantidae) to resist opportunistic infections

– B.M. Chandranaiik, Vardhaman Patil, D. Rathnamma, G.S. Mamatha, K.S. Umashankar, D.N. Nagaraju & S.M. Byregowda, Pp. 20951–20963

### Cases of fatal electrocution of the endangered Javan Gibbons (Mammalia: Primates: Hylobatidae) by power lines

– Yoonjung Yi, Soojung Ham, Rahayu Oktaviani, Mia Clarissa Dewi, Muhammad Nur, Ani Mardastuti & Jae. C. Choe, Pp. 20964–20969

### Nesting habits of the Baya Weaver *Ploceus philippinus* (Linnaeus, 1766) in the agricultural landscape of Tindivanam, Tamil Nadu, India

– M. Pandian, Pp. 20970–20987

### A checklist of avifauna from different habitats of semi-arid landscape in western parts (Mandsaur and Ratlam districts) of Madhya Pradesh, India

– Koushik Bhattacharjee & Shuvadip Adhikari, Pp. 20988–21001

### Post-release growth of captive-reared Gharial *Gavialis gangeticus* (Gmelin, 1789) (Reptilia: Crocodylia: Gavialidae) in Chitwan National Park, Nepal

– Bed Bahadur Khadka, Ashish Bashyal & Phoebe Griffith, Pp. 21002–21009

### Occurrence patterns of herpetofauna in different habitat types of western Terai Arc Landscape, India

– Gajendra Singh Mehra, Nakulananda Mohanty & Sushil Kumar Dutta, Pp. 21010–21018

### Ichthyo-parasitological studies in northeastern India

– Arup Kumar Hazarika & Bobita Bordoloi, Pp. 21019–21024

### Serosurvey of viral pathogens in free-ranging dog populations in the high altitude Trans-Himalayan region

– Chandrima Home, Ajay Bijoor, Yash Veer Bhatnagar & Abi Tamim Vanak, Pp. 21025–21031

### Diversity and distribution of mantis shrimps (Arthropoda: Crustacea: Stomatopoda) in the Gulf of Kachchh, Gujarat, India

– Piyush Vadher, Hitesh Kardani & Imtiyaz Beleem, Pp. 21032–21042

### Bionomics study of *Mansonia* (Diptera: Culicidae) in a filariasis-endemic area of Sedang Village, Banyuasin Regency, South Sumatra, Indonesia

– Rini Pratiwi, Chairil Anwar, Ahmad Ghiffari & Adri Huda, Pp. 21043–21054

### Plant species diversity in a tropical semi-evergreen forest in Mizoram (northeastern India): assessing the effectiveness of community conservation

– S.T. Lalzarzovi & Lalnuntluanga, Pp. 21055–21067

### Floristic studies on mangrove vegetation of Kanika Island, Bhadrak District, Odisha, India

– P. Poornima, Pp. 21068–21075

### Two new varieties of *Russula* Pers. (Basidiomycota: Russulaceae) from Sal forests of Shiwaliks, India

– Jitender Kumar & Narendra Singh Atri, Pp. 21076–21083

### New additions to the lichen biota of Assam from Dhubri district, northeastern India

– Suparna Biswas, Rebecca Daimari, Pungbili Islary, Sanjeeva Nayaka, Siljo Joseph, Dalip Kumar Upreti & Pranjit Kumar Sarma, Pp. 21084–21090

### Genus *Gymnopilus* (Agaricales: Strophariaceae): additions to the agarics of India

– N.A. Wani, M. Kaur & N.A. Malik, Pp. 21091–21101

## Review

### Environmental DNA as a tool for biodiversity monitoring in aquatic ecosystems – a review

– Manisha Ray & Govindhaswamy Umapathy, Pp. 21102–21116

## Short Communications

### New record and update on the geographic distribution of the Egyptian Tomb Bat *Taphozous perforatus* (E. Geoffroy, 1818) in Cameroon

– Eric Moïse Bakwo Fils, Kingha Zebaze Jasmine Flora, Manfothang Dongmo Ervis, Manga Mongombe Aaron & Jan Decher, Pp. 21117–21121

### First definite record of Collared Pratincole *Glareola pratincola* Linnaeus, 1766 (Aves: Charadriiformes: Glareolidae) from Goa, India

– Rupali Pandit, Mangirish Dharwadkar & Justino Rebello, Pp. 21122–21124

## Notes

### Nectar robbing by sunbirds on the flowers of *Morinda pubescens* J.E. Smith (Rubiaceae)

– A.J. Solomon Raju, S. Sravan Kumar, G. Nagaraju, C. Venkateswara Reddy, Tebesi Peter Raliengoane, L. Kala Grace, K. Punny, K. Prathyusha & P. Srikanth, Pp. 21125–21126

## Publisher & Host

