FOOD HABITS OF SYMPATRIC LARGE HERBIVORES IN KAZIRANGA NATIONAL PARK, ASSAM, INDIA

Thesis submitted to the

Saurashtra University, Rajkot (Gujarat)

For the Award of the Degree of

DOCTOR OF PHILOSOPHY

IN

WILDLIFE SCIENCE

By

ANITA DEVI

PhD Registration No: 16801

WILDLIFE INSTITUTE OF INDIA

February 2023

FOOD HABITS OF SYMPATRIC LARGE HERBIVORES IN KAZIRANGA NATIONAL PARK, ASSAM, INDIA

Thesis submitted

For the Award of the Degree of

DOCTOR OF PHILOSOPHY

In

WILDLIFE SCIENCE

by

ANITA DEVI

to

Saurashtra University, Rajkot (Gujarat)

Under the Supervision of

Supervisor
Dr. S. A. HUSSAIN

Co-Supervisor
Dr. RUCHI BADOLA

Wildlife Institute of India, Chandrabani, Dehradun

Uttarakhand, India

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

February 2023

Citation:

Devi, A. (2023). Food habits of sympatric large herbivores in Kaziranga National Park, Assam, India. Doctoral dissertation. Wildlife Institute of India, Dehradun, India and Saurashtra University, Rajkot, India. Pp. 1-192

SAURASHTRA UNIVERSITY
P.G.T.R. Section
Main office,
First Floor,
University Road,
Rajkot - 360 005(Gujarat)
Phone No. : 2578501
Fax:(0281)2586983
www.saurashtrauniversity.edu

Accredited Grade'A' by NAAC

Ph.D. REGISTRATION CERTIFICATE

Reg.No : 16801 **Date of Registration : 1/7/2016**

This is to certify that **ANITA DEVI** has been registered as a Ph.D. Scholar under the Supervision/Guidance of **Dr. S. A. Hussain (Wildlife Institute of India, P.O. Box No. 18, Chandrabani, Dehra Dun - 248001, Uttarakhand)** in **Wild Life Science** Subject, Faculty of **Science** .

The Title of his/her thesis is "**FOOD HABITS OF SYMPATRIC LARGE HERBIVORES IN KAZIRANGA NATIONAL PARK, ASSAM, INDIA** ".

Accordingly, he/she is entitled to submit his/her thesis after completion of four semesters from the date of registration as per provisions contained in the ordinances and rules of the university pertaining to award of the Degree of Ph.D.

Date : 16 -11-2016

Section Officer

भारतीय वन्यजीव संस्थान
Wildlife Institute of India
(An Autonomous Institute under Ministry of Environment, Forest & Climate Change, Govt. of India)
पत्रपेटी सं0/Post Box No. 18, चन्द्रबनी, देहरादून/Chandrabani, Dehradun - 248001, उत्तराखण्ड, भारत/ Uttarakhand, INDIA

Azadi Ka Amrit Mahotsav

DECLARATION

I hereby declare that the thesis "**Food habits of sympatric large herbivores in Kaziranga National Park, Assam, India**" is original research conducted by me under the supervision of **Dr. S.A. Hussain** and **Dr. Ruchi Badola** of the Wildlife Institute of India. The thesis has been submitted to the **Saurashtra University, Rajkot (Gujrat)**, for the award of **Doctor of Philosophy in Wildlife Science** and has not formed the basis for the award of any other degree. It embodies my own work and observations, and in that respect, the investigation appears to advance knowledge on the subject.

Date: 31/1/2023
Place: Dehradun

Anita Devi
Doctoral Candidate

Countersigned:

Dr. S.A. Hussain
Supervisor

Dr. Ruchi Badola
Co-Supervisor

कुल सचिव / Registrar
भारतीय वन्यजीव संस्थान
WILDLIFE INSTITUTE OF INDIA
देहरादून / Dehradun

WILDLIFE INSTITUTE OF INDIA
CHANDRABANI, DEHRADUN

भारतीय वन्यजीव संस्थान
Wildlife Institute of India
(An Autonomous Institute under Ministry of Environment, Forest & Climate Change, Govt. of India)
पत्रपेटी सं०/Post Box No. 18, चन्द्रबनी, देहरादून/Chandrabani, Dehradun - 248001, उत्तराखण्ड, भारत/ Uttarakhand, INDIA

Azadi Ka Amrit Mahotsav

CERTIFICATE

This is to certify that the thesis by Ms. Anita Devi entitled **"Food habits of sympatric large herbivores in Kaziranga National Park, Assam, India"** is an original and independent research work submitted to the **Saurashtra University, Rajkot (Gujarat)**, for the award of the degree of **Doctor of Philosophy in Wildlife Science**.

Ms. **Anita Devi** has put in more than six terms of research work embodied in this thesis under our guidance and supervision. The work presented in this thesis has not been submitted for any degree of any other University or Institution.

Dr. S.A. Hussain
Supervisor

Dr. Ruchi Badola
Co-Supervisor

कुल सचिव / Registrar
भारतीय वन्यजीव संस्थान
WILDLIFE INSTITUTE OF INDIA
देहरादून / Dehradun

Forwarded:

Dr. Y.V. Jhala
Dean, Faculty of Wildlife Sciences,
Wildlife Institute of India
Chandrabani, Dehradun- 248001
Uttarakhand

संकायाध्यक्ष / Dean
भारतीय वन्यजीव संस्थान
WILDLIFE INSTITUTE OF INDIA
देहरादून / Dehradun

WILDLIFE INSTITUTE OF INDIA · CHANDRABANI, DEHRADUN ·

SAURASHTRA UNIVERSITY
P.G.T.R. Section,
Main Office, 1st Floor,
University Road,
Rajkot - 360 005(Gujarat)
Phone No. : 2578501
Fax:(0281)2586983
www.saurashtrauniversity.edu

पायका न सरस्वती
SAURASHTRA UNIVERSITY

Re-Accredited Grade'**A**' by NAAC

CERTIFICATE FOR PRE Ph.D. PRESENTATION

This is to certify that Ms. Anita Devi (Regd. No. 16801, 01.07.2016) made Pre Ph.D. presentation as per UGC Guide Line "University Grant Commission (Minimum Standard and Procedure for an award of Ph.D. Degree) Regulation-2009" and Saurashtra University Ordinance for Ph.D. Programme (O.Ph.D. 6.2), on the research work titled **"Food habits of sympatric large herbivores in Kaziranga National Park, Assam, India"** at the **Wildlife Institute of India, Dehra Dun**, a Research Centre of Saurashtra University, Rajkot, on **25th July 2022**. The presentation was attended by faculty members and students of the institute for feedback and comments.

I also certify that the research work was appreciated by all who were present, and the comments made by the faculty and researchers have been appropriately included in the thesis.

Dr. S.A. Hussain
Supervisor

Dr. Ruchi Badola
Co-Supervisor

कुल सचिव / Registrar
भारतीय वन्यजीव संस्थान
WILDLIFE INSTITUTE OF INDIA
देहरादून / Dehradun

Dr. Y.V. Jhala
Dean, Faculty of Wildlife Sciences,
Wildlife Institute of India

Place: Dehradun
Date: 01/02/2023

संकायाध्यक्ष / Dean
भारतीय वन्यजीव संस्थान
WILDLIFE INSTITUTE OF INDIA
देहरादून / Dehradun

WILDLIFE INSTITUTE OF INDIA
CHANDRABANI, DEHRADUN

SAURASHTRA UNIVERSITY, RAJKOT
CERTIFICATE OF PLAGIARISM CHECK

1	Name of the Research Scholar	ANITA DEVI
2	Title of the Thesis/Dissertation	FOOD HABITS OF SYMPATRIC LARGE HERBIVORES IN KAZIRANGA NATIONAL PARK, ASSAM, INDIA
3	Name of the Supervisor	DR. S.A. HUSSAIN & DR. RUCHI BADOLA
4	Department/ Institution/ Research Center	WILDLIFE INSTITUTE OF INDIA
5	Similar Content (%) identified	6%
6	Acceptable Maximum Limit	15%
7	Software Used	Turnitin
8	Date of Verification	1st February 2023
9	Submission ID	2003908758

Checked by (with Name, Designation and Signature)

Librarian: Smt. Sunita Agarwal

(Sunita Agarwal)
Librarian
Wildlife Institute of India
Dehradun

Name and Signature of the Researcher: Anita Devi

Name and Signature of the Supervisor: Dr. S.A. Hussain

संकायाध्यक्ष / Dean
भारतीय वन्यजीव संस्थान
WILDLIFE INSTITUTE OF INDIA
देहरादून / Dehradun

Name and Signature of the HOD (Co-ordinator of Department Research Committee):

Document Viewer

Turnitin Originality Report

Processed on: 01-Feb-2023 11:12 AM IST
ID: 2003908758
Word Count: 41275
Submitted: 1

PhD By Anita Devi

Similarity Index	Similarity by Source	
6%	Internet Sources:	N/A
	Publications:	6%
	Student Papers:	N/A

include quoted | include bibliography | excluding matches < 10 words | mode: quickview (classic) report | print | refresh | download

1% match ("The Ecology of Large Herbivores in South and Southeast Asia", Springer Nature, 2016)
"The Ecology of Large Herbivores in South and Southeast Asia", Springer Nature, 2016

1% match (Farshid S. Ahrestani, Ignas M. A. Heitkönig, Herbert H. T. Prins. "Diet and habitat-niche relationships within an assemblage of large herbivores in a seasonal tropical forest", Journal of Tropical Ecology, 2012)
Farshid S. Ahrestani, Ignas M. A. Heitkönig, Herbert H. T. Prins. "Diet and habitat-niche relationships within an assemblage of large herbivores in a seasonal tropical forest", Journal of Tropical Ecology, 2012

<1% match (Per Wegge. "Dry season diets of sympatric ungulates in lowland Nepal: competition and facilitation in alluvial tall grasslands", Ecological Research, 09/2006)
Per Wegge. "Dry season diets of sympatric ungulates in lowland Nepal: competition and facilitation in alluvial tall grasslands", Ecological Research, 09/2006

<1% match (Collins Ayine Nsor, Samuel K. Oppong, Emmanuel Danquah, Michael Ochem, Osei Owusu Antobre. "Spatiotemporal dynamics of terrestrial invertebrate assemblages in the riparian zone of the Wewe river, Ashanti region, Ghana", Open Life Sciences, 2020)
Collins Ayine Nsor, Samuel K. Oppong, Emmanuel Danquah, Michael Ochem, Osei Owusu Antobre. "Spatiotemporal dynamics of terrestrial invertebrate assemblages in the riparian zone of the Wewe river, Ashanti region, Ghana", Open Life Sciences, 2020

<1% match (ROBERT J. MARQUIS, IVONE R. DINIZ, HELENA C. MORAIS. "Patterns and correlates of interspecific variation in foliar insect herbivory and pathogen attack in Brazilian cerrado", Journal of Tropical Ecology, 2001)
ROBERT J. MARQUIS, IVONE R. DINIZ, HELENA C. MORAIS. "Patterns and correlates of interspecific variation in foliar insect herbivory and pathogen

attack in Brazilian cerrado", Journal of Tropical Ecology, 2001

<1% match ("The Hindu Kush Himalaya Assessment", Springer Science and Business Media LLC, 2019)
"The Hindu Kush Himalaya Assessment", Springer Science and Business Media LLC, 2019

<1% match (P. Martiniello, R. Paoletti, N. Berardo. "Effect of phenological stages on dry matter and quality components in lucerne", European Journal of Agronomy, 1997)
P. Martiniello, R. Paoletti, N. Berardo. "Effect of phenological stages on dry matter and quality components in lucerne", European Journal of Agronomy, 1997

<1% match (C. M. Begg, K. S. Begg, J. T. Toit, M. G. L. Mills. " Sexual and seasonal variation in the diet and foraging behaviour of a sexually dimorphic carnivore, the honey badger ( ) ", Journal of Zoology, 2006)
C. M. Begg, K. S. Begg, J. T. Toit, M. G. L. Mills. " Sexual and seasonal variation in the diet and foraging behaviour of a sexually dimorphic carnivore, the honey badger ( ) ", Journal of Zoology, 2006

<1% match (Faunal Heritage of Rajasthan India, 2013.)
Faunal Heritage of Rajasthan India, 2013.

<1% match (Gustavo F. M. Leite, Fabíola Turiel Costa Silva, José Francisco Júnior Gonçalves, Paulo Salles. "Effects of conservation status of the riparian vegetation on fish assemblage structure in neotropical headwater streams", Hydrobiologia, 2015)
Gustavo F. M. Leite, Fabíola Turiel Costa Silva, José Francisco Júnior Gonçalves, Paulo Salles. "Effects of conservation status of the riparian vegetation on fish assemblage structure in neotropical headwater streams", Hydrobiologia, 2015

<1% match (Borrell, A.. "Improving efficiency of water use for irrigated rice in a semi-arid tropical environment", Field Crops Research, 199706)
Borrell, A.. "Improving efficiency of water use for irrigated rice in a semi-arid tropical environment", Field Crops Research, 199706

<1% match (José R. Castelló, Brent Huffman, Colin Groves. "Bovids of the World", Walter de Gruyter GmbH, 2016)
José R. Castelló, Brent Huffman, Colin Groves. "Bovids of the World", Walter de Gruyter GmbH, 2016

<1% match (Mayumi Kawabe. "SUBCHRONIC TOXICITY STUDY OF L-ISOLEUCINE IN F344 RATS", Journal of Toxicology and Environmental Health, 1996)
Mayumi Kawabe. "SUBCHRONIC TOXICITY STUDY OF L-ISOLEUCINE IN F344 RATS", Journal of Toxicology and Environmental Health, 1996

<1% match (Renata Barreto Tostes, Luci de Senna-Valle. "Chapter 9 Medicinal Plants Used in Quilombola Communities in Piranga, State of Minas Gerais, Brazil", Springer Science and Business Media LLC, 2022)
Renata Barreto Tostes, Luci de Senna-Valle. "Chapter 9 Medicinal Plants Used in Quilombola Communities in Piranga, State of Minas Gerais, Brazil", Springer Science and Business Media LLC, 2022

<1% match (Rory J. Putman. "Competition and Resource Partitioning in

Temperate Ungulate Assemblies", Springer Nature, 1996)
Rory J. Putman. "Competition and Resource Partitioning in Temperate Ungulate Assemblies", Springer Nature, 1996

<1% match ("Himalayan Biodiversity in the Changing World", Springer Science and Business Media LLC, 2012)
"Himalayan Biodiversity in the Changing World", Springer Science and Business Media LLC, 2012

<1% match (Subham Banerjee, Rajashekhar Niyogi, Mriganka Shekhar Sarkar, Robert John. "Assessing the vulnerability of protected areas in the eastern Himalayas based on their biological, anthropogenic, and environmental aspects (VSI: Mountainous Regions)", Trees, Forests and People, 2022)
Subham Banerjee, Rajashekhar Niyogi, Mriganka Shekhar Sarkar, Robert John. "Assessing the vulnerability of protected areas in the eastern Himalayas based on their biological, anthropogenic, and environmental aspects (VSI: Mountainous Regions)", Trees, Forests and People, 2022

<1% match (Alice J. Michel, Lewis M. Ward, Shana K. Goffredi, Katherine S. Dawson et al. "The gut of the finch: uniqueness of the gut microbiome of the Galápagos vampire finch", Microbiome, 2018)
Alice J. Michel, Lewis M. Ward, Shana K. Goffredi, Katherine S. Dawson et al. "The gut of the finch: uniqueness of the gut microbiome of the Galápagos vampire finch", Microbiome, 2018

<1% match (K. Sankar, H. S. Pabla, C. K. Patil, Parag Nigam et al. " Home Range, Habitat Use and Food Habits of Re-Introduced Gaur ( ) in Bandhavgarh Tiger Reserve, Central India ", Tropical Conservation Science, 2013)
K. Sankar, H. S. Pabla, C. K. Patil, Parag Nigam et al. " Home Range, Habitat Use and Food Habits of Re-Introduced Gaur ( ) in Bandhavgarh Tiger Reserve, Central India ", Tropical Conservation Science, 2013

<1% match (Lei Luo, Xinyuan Wang, Huadong Guo, Lanwei Zhu et al. "Eighteen years (2001-2018) of forest habitat loss across the asian elephant’s range and its drivers", Science Bulletin, 2022)
Lei Luo, Xinyuan Wang, Huadong Guo, Lanwei Zhu et al. "Eighteen years (2001-2018) of forest habitat loss across the asian elephant’s range and its drivers", Science Bulletin, 2022

<1% match (Demment, Montague W., and Peter J. Van Soest. "A Nutritional Explanation for Body-Size Patterns of Ruminant and Nonruminant Herbivores", The American Naturalist, 1985.)
Demment, Montague W., and Peter J. Van Soest. "A Nutritional Explanation for Body-Size Patterns of Ruminant and Nonruminant Herbivores", The American Naturalist, 1985.

<1% match (Anwaruddin Choudhury. "Railway threat to Kaziranga", Oryx, 2009)
Anwaruddin Choudhury. "Railway threat to Kaziranga", Oryx, 2009

<1% match (Sabhyata Lamichhane, Gopal Khanal, Jhamak Bahadur Karki, Chandramani Aryal, Suman Acharya. "Natural and anthropogenic correlates of habitat use by wild ungulates in Shuklaphanta National Park, Nepal", Global Ecology and Conservation, 2020)
Sabhyata Lamichhane, Gopal Khanal, Jhamak Bahadur Karki, Chandramani Aryal, Suman Acharya. "Natural and anthropogenic correlates of habitat use

by wild ungulates in Shuklaphanta National Park, Nepal", Global Ecology and Conservation, 2020

<1% match (M. A. Badejo, G. Tian, M. A. Badejo, G. Tian. "Abundance of soil mites under four agroforestry tree species with contrasting litter quality", Biology and Fertility of Soils, 1999)
M. A. Badejo, G. Tian, M. A. Badejo, G. Tian. "Abundance of soil mites under four agroforestry tree species with contrasting litter quality", Biology and Fertility of Soils, 1999

<1% match (Varun R. Goswami, Divya Vasudev, Bhavendu Joshi, Prity Hait, Pragyan Sharma. "Coupled effects of climatic forcing and the human footprint on wildlife movement and space use in a dynamic floodplain landscape", Science of The Total Environment, 2021)
Varun R. Goswami, Divya Vasudev, Bhavendu Joshi, Prity Hait, Pragyan Sharma. "Coupled effects of climatic forcing and the human footprint on wildlife movement and space use in a dynamic floodplain landscape", Science of The Total Environment, 2021

<1% match (E. C. Okogbue. "Hourly and daily clearness index and diffuse fraction at a tropical station, Ile-Ife, Nigeria", International Journal of Climatology, 2009)
E. C. Okogbue. "Hourly and daily clearness index and diffuse fraction at a tropical station, Ile-Ife, Nigeria", International Journal of Climatology, 2009

<1% match (Ralph C. Villar, Abdulqadir J. Nashwan, John Paul Silang, Ebtsam Abou Hashish et al. "The Impact of Using DASH First Element as a Pre-Briefing Tool on Nurse Competency and Learning during Code Blue Simulation: A Mixed-Methods Study", Research Square Platform LLC, 2023)
Ralph C. Villar, Abdulqadir J. Nashwan, John Paul Silang, Ebtsam Abou Hashish et al. "The Impact of Using DASH First Element as a Pre-Briefing Tool on Nurse Competency and Learning during Code Blue Simulation: A Mixed-Methods Study", Research Square Platform LLC, 2023

<1% match (Sandeep Kumar Gupta, Ajit Kumar, Sangeeta Angom, Bhim Singh, Mirza Ghazanfar Ullah Ghazi, Chongpi Tuboi, Syed Ainul Hussain. "Genetic analysis of endangered hog deer (Axis porcinus) reveals two distinct lineages from the Indian subcontinent", Scientific Reports, 2018)
Sandeep Kumar Gupta, Ajit Kumar, Sangeeta Angom, Bhim Singh, Mirza Ghazanfar Ullah Ghazi, Chongpi Tuboi, Syed Ainul Hussain. "Genetic analysis of endangered hog deer (Axis porcinus) reveals two distinct lineages from the Indian subcontinent", Scientific Reports, 2018

<1% match (Érika Maria Neif, Rômulo Diego de Lima Behrend, Liliana Rodrigues. "Seasonal dynamics of the structure of epiphytic algal community on different substrates from a Neotropical floodplain", Brazilian Journal of Botany, 2013)
Érika Maria Neif, Rômulo Diego de Lima Behrend, Liliana Rodrigues. "Seasonal dynamics of the structure of epiphytic algal community on different substrates from a Neotropical floodplain", Brazilian Journal of Botany, 2013

<1% match (Arjun B. Potter, Matthew C. Hutchinson, Johan Pansu, Bart Wursten, Ryan A. Long, Jonathan M. Levine, Robert M. Pringle. "Mechanisms of dietary resource partitioning in large-herbivore assemblages: a plant-trait-based approach", Journal of Ecology, 2022)
Arjun B. Potter, Matthew C. Hutchinson, Johan Pansu, Bart Wursten, Ryan A. Long, Jonathan M. Levine, Robert M. Pringle. "Mechanisms of dietary

resource partitioning in large-herbivore assemblages: a plant-trait-based approach", Journal of Ecology, 2022

<1% match (Resource Ecology, 2008.)
Resource Ecology, 2008.

<1% match (Shimane W. Makhabu. "Resource partitioning within a browsing guild in a key habitat, the Chobe Riverfront, Botswana", Journal of Tropical Ecology, 2005)
Shimane W. Makhabu. "Resource partitioning within a browsing guild in a key habitat, the Chobe Riverfront, Botswana", Journal of Tropical Ecology, 2005

<1% match (Girish Arjun Punjabi, M.K. Rao. "Large herbivore populations outside protected areas in the human-dominated Western Ghats, India", Mammalian Biology, 2017)
Girish Arjun Punjabi, M.K. Rao. "Large herbivore populations outside protected areas in the human-dominated Western Ghats, India", Mammalian Biology, 2017

<1% match (Munmi Saikia, Atasi Patra Maiti, Anuradha Devi. "Effect of habitat complexity on rhinoceros and tiger population model with additional food and poaching in Kaziranga National Park, Assam", Mathematics and Computers in Simulation, 2020)
Munmi Saikia, Atasi Patra Maiti, Anuradha Devi. "Effect of habitat complexity on rhinoceros and tiger population model with additional food and poaching in Kaziranga National Park, Assam", Mathematics and Computers in Simulation, 2020

<1% match (Pradeep K. Mathur, Harish Kumar, John F. Lehmkuhl, Anshuman Tripathi, Vishwas B. Sawarkar, Rupak De. "Mammal indicator species for protected areas and managed forests in a landscape conservation area of northern India", Biodiversity and Conservation, 2010)
Pradeep K. Mathur, Harish Kumar, John F. Lehmkuhl, Anshuman Tripathi, Vishwas B. Sawarkar, Rupak De. "Mammal indicator species for protected areas and managed forests in a landscape conservation area of northern India", Biodiversity and Conservation, 2010

<1% match (Subrata Nandy, M. Saranya, Ritika Srinet. "Spatio-temporal variability of water use efficiency and its drivers in major forest formations in India", Remote Sensing of Environment, 2022)
Subrata Nandy, M. Saranya, Ritika Srinet. "Spatio-temporal variability of water use efficiency and its drivers in major forest formations in India", Remote Sensing of Environment, 2022

<1% match (A. Monadjem. " Population dynamics of and (Muridae: Rodentia) in a subtropical grasslandin Swaziland ", African Journal of Ecology, 2001)
A. Monadjem. " Population dynamics of and (Muridae: Rodentia) in a subtropical grasslandin Swaziland ", African Journal of Ecology, 2001

<1% match (Adam Jeziorski, Andrew M. Paterson, John P. Smol. "Changes since the onset of acid deposition among calcium-sensitive cladoceran taxa within softwater lakes of Ontario, Canada", Journal of Paleolimnology, 2012)
Adam Jeziorski, Andrew M. Paterson, John P. Smol. "Changes since the onset of acid deposition among calcium-sensitive cladoceran taxa within softwater lakes of Ontario, Canada", Journal of Paleolimnology, 2012

<1% match (Dandan Gao, Faming Wang, Jian Li, Shiqin Yu, Zhian Li, Jie Zhao. "Soil nematode communities as indicators of soil health in different land use types in tropical area", Nematology, 2020)
Dandan Gao, Faming Wang, Jian Li, Shiqin Yu, Zhian Li, Jie Zhao. "Soil nematode communities as indicators of soil health in different land use types in tropical area", Nematology, 2020

<1% match (L Brabin. "Biological and hormonal markers of chlamydia, human papillomavirus, and bacterial vaginosis among adolescents attending genitourinary medicine clinics", Sexually Transmitted Infections, 2005)
L Brabin. "Biological and hormonal markers of chlamydia, human papillomavirus, and bacterial vaginosis among adolescents attending genitourinary medicine clinics", Sexually Transmitted Infections, 2005

<1% match (M. A. Saleque. "Response of wetland rice to potassium in farmers' fields of the Barind tract of Bangladesh", Journal of Plant Nutrition, 01/1998)
M. A. Saleque. "Response of wetland rice to potassium in farmers' fields of the Barind tract of Bangladesh", Journal of Plant Nutrition, 01/1998

<1% match (Nityaranjan Nath, Dhrubajyoti Sahariah, Gowhar Meraj, Jatan Debnath et al. "Land Use and Land Cover Change Monitoring and Prediction of a UNESCO World Heritage Site: Kaziranga Eco-Sensitive Zone Using Cellular Automata-Markov Model", Land, 2023)
Nityaranjan Nath, Dhrubajyoti Sahariah, Gowhar Meraj, Jatan Debnath et al. "Land Use and Land Cover Change Monitoring and Prediction of a UNESCO World Heritage Site: Kaziranga Eco-Sensitive Zone Using Cellular Automata-Markov Model", Land, 2023

<1% match (Ankit Shankar Pacha, Parag Nigam, Bivash Pandav, Samrat Mondol. "Sequencing and annotation of the endangered wild buffalo (Bubalus arnee) mitogenome for taxonomic assessment", Molecular Biology Reports, 2021)
Ankit Shankar Pacha, Parag Nigam, Bivash Pandav, Samrat Mondol. "Sequencing and annotation of the endangered wild buffalo (Bubalus arnee) mitogenome for taxonomic assessment", Molecular Biology Reports, 2021

<1% match (R. J. Bowell, R. K. Ansah. "Trace element budget in an African savannah ecosystem", Biogeochemistry, 1993)
R. J. Bowell, R. K. Ansah. "Trace element budget in an African savannah ecosystem", Biogeochemistry, 1993

<1% match ("Microbial Biodiversity, Biotechnology and Ecosystem Sustainability", Springer Science and Business Media LLC, 2023)
"Microbial Biodiversity, Biotechnology and Ecosystem Sustainability", Springer Science and Business Media LLC, 2023

<1% match (G. Pietrzak, A. Curnier. "Large deformation frictional contact mechanics: continuum formulation and augmented Lagrangian treatment", Computer Methods in Applied Mechanics and Engineering, 1999)
G. Pietrzak, A. Curnier. "Large deformation frictional contact mechanics: continuum formulation and augmented Lagrangian treatment", Computer Methods in Applied Mechanics and Engineering, 1999

<1% match (M. E. T. Cunha, M. J. S. Yabe, I. Lobo, R. Aravena. "Isotopic Composition as a Tool for Assessment of Origin and Dynamic of Organic Matter in Tropical Freshwater", Environmental Monitoring and Assessment,

2006)
M. E. T. Cunha, M. J. S. Yabe, I. Lobo, R. Aravena. "Isotopic Composition as a Tool for Assessment of Origin and Dynamic of Organic Matter in Tropical Freshwater", Environmental Monitoring and Assessment, 2006

<1% match (M. N. M. Ibrahim. "Solubility of mineral elements present in ruminant feeds", The Journal of Agricultural Science, 06/1990)
M. N. M. Ibrahim. "Solubility of mineral elements present in ruminant feeds", The Journal of Agricultural Science, 06/1990

<1% match (Marco Mariotti, Filippo Fratini, Domenico Cerri, Victoria Andreuccetti et al. "Use of Fresh Scotta Whey as an Additive for Alfalfa Silage", Agronomy, 2020)
Marco Mariotti, Filippo Fratini, Domenico Cerri, Victoria Andreuccetti et al. "Use of Fresh Scotta Whey as an Additive for Alfalfa Silage", Agronomy, 2020

<1% match (Masato Abe, Michael Troilo, Orgil Batsaikhan. "Financing small and medium enterprises in Asia and the Pacific", Journal of Entrepreneurship and Public Policy, 2015)
Masato Abe, Michael Troilo, Orgil Batsaikhan. "Financing small and medium enterprises in Asia and the Pacific", Journal of Entrepreneurship and Public Policy, 2015

<1% match (B. Pisarikova, Z. Zraly, S. Kracmar, M. Trckova, I. Herzig. "The use of amaranth (genus AmaranthusL.) in the diets for broiler chickens", Veterinární medicína, 2006)
B. Pisarikova, Z. Zraly, S. Kracmar, M. Trckova, I. Herzig. "The use of amaranth (genus AmaranthusL.) in the diets for broiler chickens", Veterinární medicína, 2006

<1% match (Elizabeth K. Wood, J. Dee Higley. "Chapter 471 Parenting", Springer Science and Business Media LLC, 2022)
Elizabeth K. Wood, J. Dee Higley. "Chapter 471 Parenting", Springer Science and Business Media LLC, 2022

<1% match (Hofbauer, J.. "Evolution in games with randomly disturbed payoffs", Journal of Economic Theory, 200701)
Hofbauer, J.. "Evolution in games with randomly disturbed payoffs", Journal of Economic Theory, 200701

<1% match (Joel T. Heinen, Ramchandra Kandel. " Threats to a small population: a census and conservation recommendations for wild buffalo in Nepal ", Oryx, 2006)
Joel T. Heinen, Ramchandra Kandel. " Threats to a small population: a census and conservation recommendations for wild buffalo in Nepal ", Oryx, 2006

<1% match (Nur Alizati Nabila Giarat Ali, Mohd Lutfi Abdullah, Siti Azizah Mohd Nor, Tan Min Pau et al. "A review of the genus Rusa in the indo-malayan archipelago and conservation efforts", Saudi Journal of Biological Sciences, 2020)
Nur Alizati Nabila Giarat Ali, Mohd Lutfi Abdullah, Siti Azizah Mohd Nor, Tan Min Pau et al. "A review of the genus Rusa in the indo-malayan archipelago and conservation efforts", Saudi Journal of Biological Sciences, 2020

<1% match (Palmer, A.S.. "Sediment profile characterisation at

contaminated and reference locations in the Windmill Islands, East Antarctica", Marine Pollution Bulletin, 201009)
Palmer, A.S.. "Sediment profile characterisation at contaminated and reference locations in the Windmill Islands, East Antarctica", Marine Pollution Bulletin, 201009

<1% match (Ecology and Conservation of Tropical Marine Faunal Communities, 2013.)
Ecology and Conservation of Tropical Marine Faunal Communities, 2013.

<1% match (U. Kuhn. "Exchange of short-chain monocarboxylic acids by vegetation at a remote tropical forest site in Amazonia", Journal of Geophysical Research, 2002)
U. Kuhn. "Exchange of short-chain monocarboxylic acids by vegetation at a remote tropical forest site in Amazonia", Journal of Geophysical Research, 2002

<1% match (Demelash Woldeyohannes, Yohannes Tekalegn, Biniyam Sahiledengle, Desta Erkalo, Zeleke Hailemariam, Lillian Mwanri. "Preconception Care in Sub Saharan Africa: A Systematic Review and Meta-analysis on Prevalence and Its Correlation With Knowledge Level Among Women in Reproductive Age Group", Research Square Platform LLC, 2021)
Demelash Woldeyohannes, Yohannes Tekalegn, Biniyam Sahiledengle, Desta Erkalo, Zeleke Hailemariam, Lillian Mwanri. "Preconception Care in Sub Saharan Africa: A Systematic Review and Meta-analysis on Prevalence and Its Correlation With Knowledge Level Among Women in Reproductive Age Group", Research Square Platform LLC, 2021

<1% match (José Jailson Lima Bezerra, Anderson Angel Vieira Pinheiro, Emiliano de Oliveira Barreto. "Medicinal plants used in the treatment of asthma in different regions of Brazil: a comprehensive review of ethnomedicinal evidence, preclinical pharmacology and clinical trials", Phytomedicine Plus, 2022)
José Jailson Lima Bezerra, Anderson Angel Vieira Pinheiro, Emiliano de Oliveira Barreto. "Medicinal plants used in the treatment of asthma in different regions of Brazil: a comprehensive review of ethnomedicinal evidence, preclinical pharmacology and clinical trials", Phytomedicine Plus, 2022

<1% match (Leslie, David M. "Rusa unicolor (Artiodactyla: Cervidae)", Mammalian Species, 2011.)
Leslie, David M. "Rusa unicolor (Artiodactyla: Cervidae)", Mammalian Species, 2011.

<1% match (A. Verhoef, S.J. Allen, C.R. Lloyd. "Seasonal variation of surface energy balance over two Sahelian surfaces", International Journal of Climatology, 1999)
A. Verhoef, S.J. Allen, C.R. Lloyd. "Seasonal variation of surface energy balance over two Sahelian surfaces", International Journal of Climatology, 1999

<1% match (Dinerstein, E.. "An ecological survey of the Royal Karnali-Bardia Wildlife Reserve, Nepal. Part II: Habitat/animal interactions", Biological Conservation, 197912)
Dinerstein, E.. "An ecological survey of the Royal Karnali-Bardia Wildlife Reserve, Nepal. Part II: Habitat/animal interactions", Biological Conservation, 197912

<1% match (Sabine Tebbich. "The ecology of tool-use in the woodpecker finch (Cactospiza pallida)", Ecology Letters, 9/2002)
Sabine Tebbich. "The ecology of tool-use in the woodpecker finch (Cactospiza pallida)", Ecology Letters, 9/2002

EXECUTIVE SUMMARY 1. Globally, Africa, with 94 ungulate species, represents the highest species richness among all continents. India is represented by 39 ungulate species and 14 terrestrial herbivores with a body mass greater than 100 kg. These multispecies assemblages of terrestrial mammalian herbivores of diverse body sizes share the multiple terrestrial ecosystems in India. Persistence of these multispecies systems without conflict and mechanisms facilitating the stable coexistence of many similar species is understudied. A better understanding of the niche of animals is crucial for understanding the community dynamics of dependent consumers. Foraging is a fundamental element of a niche and is important for making assumptions about the behaviour, physiology, morphology and population dynamics of predators, prey and competitors. Forage availability and quality, and body mass have been the cornerstone of understanding the foraging ecology of large herbivores. Based on the preference for the two major plant types viz., monocots (grasses and sedges) and dicots (shrubs and trees), herbivores are categorized as grazers (feeds on graminoids or monocots), browsers (feeds on browse or dicots), or mixed feeders (feed on both monocots and dicots). Thus, any changes in the consumption of monocots (grazing) and dicots (browsing) due to changes in their quantity and quality result in changed diet compositions. Over time, various theories and explanations have helped in understanding the community and foraging ecology of large herbivores, most of which have emerged from Africa, Europe and North America. While India has contributed little to the science of large herbivore foraging ecology at the community level, possibly because large herbivore assemblages in India have low species richness, which provides low sample sizes and statistical power to validate any community ecology theory. Additionally, most of the species-rich large herbivore assemblages in India inhabit forested habitats, which has made it difficult to study these large herbivore assemblages in India. Therefore, there exists an information gap that needs to be filled. Kaziranga National Park (KNP) in the Brahmaputra floodplains provides an opportunity to examine the community ecology of mega- and meso-herbivores in an ecosystem subject to human pressure and susceptible to xiv climate change. Thus, the present study was conducted in KNP and focused on six large herbivores (SLH) of different body sizes, specifically three mega-herbivores – Greater one-horned rhino (Rhinoceros unicornis), Asian elephant (Elephas maximus) and Asiatic wild buffalo (Bubalus arnee), and three meso-herbivores – swamp deer (Rucervus duvaucelii), hog deer (Axis porcinus) and sambar (Rusa unicolor). The study aimed a) to examine the diet composition of six sympatric large herbivores (greater one-horned rhinoceros, Asian elephant, Asiatic wild buffalo, swamp deer, hog deer and sambar) in KNP in terms of forage species and their quantity consumed; b) to determine the food preference and compare the seasonal diet overlap among the study species; and c) to determine the seasonal nutrient content and variation in the utilization pattern based on the nutrient quality of the major forage utilized by the six study species. 2. KNP, in the north-eastern Indian state of Assam, is situated in the floodplains of the Brahmaputra River, which runs along the northern boundary of the Park;

*T*able of *C*ontents

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

PUBLICATIONS

List of Publications

Devi, A., Hussain, S. A., Sharma, M., Gopi, G. V., & Badola, R (2022). Seasonal pattern of food habits of large herbivores in riverine alluvial grasslands of Brahmaputra floodplains, Assam. *Scientific Reports*, *12*(1), 482. https://doi.org/10.1038/s41598-021-04295-4. **ISSN: 2045-2322.**

List of Conferences

International conferences

Devi, A., Hussain, S. A., Sharma, M., & Badola, R. (2022). Biological invasion by livestock and dogs in wet grasslands of Brahmaputra floodplains of Assam affecting its integrity. Oral presentation (virtual) at Asian Grassland Conference, 19th – 21st April 2022, **Abstract No. OP03**, 25.

Sharma, M., **Devi. A**., Hussain, S. A., & Badola, R. (2022). Vegetation composition of wet grasslands of Kaziranga National Park, Assam, India. Oral poster presentation (virtual) at Asian Grassland Conference, 19th – 21st April 2022, **Abstract No. PS49**, 66.

Institutional conferences

Devi, A., Sharma, M., Hussain, S. A., Badola, R. & Gopi, G. V (2016). Food habits of large herbivores of Kaziranga National Park, Assam. Oral poster presentation at 30th Annual Research Seminar, 29th – 30th September 2016, Wildlife Institute of India, Dehradun, India.

Sharma, M., **Devi, A**., Hussain, S. A., Badola, R. & Gopi, G. V (2016). Patterns of biomass production by the wet grasslands of Kaziranga National Park, Assam. Oral poster presentation at 30th Annual Research Seminar, 29th – 30th September 2016, Wildlife Institute of India, Dehradun, India.

ACKNOWLEDGEMENT

The enlightening journey of my Ph.D. would have been incomplete without the inspiration and assistance of many people, some of whom have been central from the inception to the completion of this thesis.

First and foremost, I want to thank my advisors Dr. Syed Ainul Hussain, Former Scientist G, Wildlife Institute of India (WII)/Project Manager, NMCG-WII Ganga Biodiversity Project, and Dr. Ruchi Badola, Scientist G & Registrar, WII. My doctoral research under their guidance was certainly the most academically rewarding experience of my life, for which I am ever grateful to them. I will always be thankful to Dr. Hussain for encouraging me to pursue my research career in this particular subject. My long association with him as his student provided me with academic enrichment and helped me grow mentally to deal with various difficulties in life. I feel extremely lucky to have had him as a teacher from the beginning. With his immense knowledge and expertise, he supported me in every step of my Ph.D. work, whether it was developing the research questions, performing field work, analyzing the data, or writing the manuscript. The effort to pen down his contribution in this manner will probably never be enough. I would like to thank you for bearing with all my drawbacks throughout these years. Without your guidance and support, this research work would not have been possible. Dr. Badola, with her profound knowledge and experience, has always guided and supported me throughout my academic journey. Her enthusiasm has always been a source of positivity and helped in the research and on the personal front. The perpetual encouragement, passion, and practical guidance she provided me throughout my research work will be remembered and appreciated forever by me. I thank both of them for believing in me and providing me with the opportunity to explore my abilities to complete my work sincerely. I like to thank Dr. S.P. Yadav, Director, WII and Dr. Y.V. Jhala, Dean, Faculty of Wildlife Sciences, WII, for providing logistic and technical support and encouragement throughout the study.

At the WII, I would like to thank Dr. J.A. Johnson, Faculty, WII, and Dr. K. Sankar, Former Faculty, WII, for making laboratory work easier by providing the facilities in the research laboratory and their invaluable support during laboratory analysis. I acknowledge Dr. V.P. Uniyal, Former Scientist G & Nodal Officer, WII, for guiding me during Ph.D. registration and submission. I am thankful to Dr. S.P. Goyal, Faculty, WII, for moral support and guidance during laboratory analysis. I would like to thank Dr. Bitapi Sinha, Scientist G & Research Coordinator, for helping with numerous official works. I would also like to thank Dr. Suthirtha Dutta, Scientist D, WII, for motivating me to learn new tools for statistical analysis.

I would like to thank all the research laboratory staff, especially Mr. Vinod Thakur, Mr. Rakesh Sundriyal and Mr. Ajay Sharma, for their continuous support. I would also like to thank my laboratory assistant, Mr. Ajay Singhal and Mr. Ram, for their immense support and assistance during the laboratory work.

I thank the entire staff of WII, particularly the friendly and cooperative administration, academic sections, and library personnel, for helping me whenever required. Mr. Rajesh Thapa, Mr. Sukumar, Mr. Lekhnath Sharma, and Mr. Muthu Veerappan helped me in the computer section. The library staff Mr. Y.S. Verma, Mr. M.M. Uniyal, Ms. Shashi, Ms. Sunita, and Ms. Nidhi, for always helping and cooperating. To Mr. Virendra, I am thankful for cheerfully printing. Mr. P.K. Agarwal, Mr. Joginder and Mr. Kharak Singh for their continuous support in the administration and finance Departments.

This doctoral work was done under a research project entitled “Pattern of biomass production by wetlands and its use by wild ungulates in Kaziranga landscape”, funded by “Department of Science and Technology”. I am highly indebted and grateful to the funding agency for believing in this work. I would also like to thank Assam Forest Department for granting permission to conduct research in the Kaziranga Tiger Reserve (KTR) and the Forest Department staff at the Agoratoli, Bokakhat, Kohora and Bagori offices for their help during field surveys and data collection.

I would like to thank Mr. P. C. Shukla, former CWLW, Assam, for providing permission to conduct fieldwork smoothly. This doctoral work wouldn’t have been possible without the help of Mr. N. K. Vasu and M. K. Yadav, former Directors, KTR. I acknowledge Mr. Rabin Sharma, Research officer, KTR, for his kind support during the study. This doctoral work wouldn’t have been possible without the help of Mr. S. K Seal Sharma, Former Division Forest Officer, KTR. I would like to thank Mr.

Sunnydeo Indradeo Choudhary, Former Assistant Conservator of Forests, KTR, for his kind support during the study. I would like to thank Mr. Pradipta Borua, Mr. Mukul Tamuli, Mr. Salim Ahmed, and Mr. Jinaram Bordoloi, Former Range officers, KTR, for providing logistic support during the field data collection. I thank all the forest guards and staff members of the KTR for their support and cooperation.

Words are not enough to thank my friend and colleague, Ms. Monika Sharma, who contributed to shaping my thesis. She helped me with the data collection and analysis and was always there to advise me. I am fortunate to have a competent, caring, loving best friend like you. Thanks for believing, supporting and encouraging my work from time to time. This research work wouldn't have been possible without the help of Dr. Chongpi Tuboi. Her moral support and cheerful companionship in the field and laboratory analysis are deeply appreciated. I would also like to thank Dr. K. Muthamizh Selvan for always helping and encouraging me with new research ideas during fieldwork. I am thankful to my field team for helping conduct data collection smoothly. I am thankful to Ms. Priti Kumari for helping during field data collection. I would like to thank my driver and field assistant, Nipu da, for his delightful company and for sharing valuable information during the fieldwork. I am also thankful to his family for hosting my team and me occasionally. I am grateful to field assistants Deva, Amit and Aakash for their help and support during fieldwork.

I am thankful to my competent, cooperative seniors, colleagues and friends at WII. I am thankful to my friend and colleague, Ms. Amanat Kaur Gill, for her help in thesis editing and encouraging words to finish my thesis on time. Thanks for constantly reminding me to take a break occasionally. I am also thankful to my senior colleague Dr. Shivani Barthwal for her invaluable support and encouragement that helped me to finish my thesis on time. I have learned a lot under her guidance, which greatly enhanced my capabilities and skills. Without her immense patience and cooperation, I would never have reached this point. I thank my senior colleague, Dr. Pariva Dobriyal, for her kind suggestions and help during the research work. Thank you, Pariva Di, for sharing your experiences, suggestions, and all the cheerful dances. I am also thankful to Dr. Niladri Dasgupta for his support and encouragement. I am also grateful to Dr. Upma Manral, for her never-ending encouragement, emotional support and friendship.

I thank my colleague, Mr. Zeeshan Ali, for helping me prepare the maps. I am thankful to Mr. Goura Chandra Das for helping me with laboratory analysis and always encouraging me. I would also like to thank Ms. Sakshi Rana for her help and support. I also want to thank my friend Ms. Michelle Irengbam for always hosting me and boosting my confidence. I am grateful to Mr. Surya Prasad Sharma for his guidance and moral support. I would also like to thank Dr. Rohitashva Shukla and Dr. Soumya Das for their kind suggestions that encouraged me to learn new analytical software. I would also like to thank Dr. Sangeeta Angom for her encouraging words. I would also like to thank Aditi Dev, Narendra Mohan, Monika Mehralu, Rupali Nayal, Deepika Dogra, Ekta Sharma, Saurav Gawan, Ashish Kumar Panda, Ravindra Nath Tripathi, Aishwarya Ramachandran, Shatakshi Sharma, Neha Sharma, Megha Thapa, Srijani Guha, Aakash Rawat and Aftab Alam Usmani for their moral support and encouragement. The assistance provided to me by Narendra Mohan, Monika Mehralu, Gyan Salambatti and Rupali Nayal is deeply appreciated.

I would consider myself fortunate to complete this journey under my family’s support, guidance, encouragement, blessings, and love. This academic journey wouldn’t have been possible without the emotional support of my mother, Mrs. Prem Kour. She always encouraged and inspired me to pursue my dreams. Thank you, mom, for being so understanding and patient with me. I am grateful for the confidence and faith that my father, Mr. Azad Pal, had in me throughout my journey. Thank you, papa, for being there whenever I needed you. I am grateful to my brothers, Sonu and Manish, for making my time more comfortable and enjoyable. I am grateful to my sisters-in-law, Varsha and Pooja, for cheering me through my ups and down. I am grateful to my nieces Pari and Dishu and nephew Yuvi, who make me realize that this journey is not only about academic learning but also about being happy and calm in extreme situations.

Anita Devi

EXECUTIVE SUMMARY

1. Globally, Africa, with 94 ungulate species, represents the highest species richness among all continents. India is represented by 39 ungulate species and 14 terrestrial herbivores with a body mass greater than 100 kg. These multispecies assemblages of terrestrial mammalian herbivores of diverse body sizes share the multiple terrestrial ecosystems in India. Persistence of these multispecies systems without conflict and mechanisms facilitating the stable coexistence of many similar species is understudied. A better understanding of the niche of animals is crucial for understanding the community dynamics of dependent consumers. Foraging is a fundamental element of a niche and is important for making assumptions about the behaviour, physiology, morphology and population dynamics of predators, prey and competitors. Forage availability and quality, and body mass have been the cornerstone of understanding the foraging ecology of large herbivores. Based on the preference for the two major plant types *viz.*, monocots (grasses and sedges) and dicots (shrubs and trees), herbivores are categorized as grazers (feeds on graminoids or monocots), browsers (feeds on browse or dicots), or mixed feeders (feed on both monocots and dicots). Thus, any changes in the consumption of monocots (grazing) and dicots (browsing) due to changes in their quantity and quality result in changed diet compositions. Over time, various theories and explanations have helped in understanding the community and foraging ecology of large herbivores, most of which have emerged from Africa, Europe and North America. While India has contributed little to the science of large herbivore foraging ecology at the community level, possibly because large herbivore assemblages in India have low species richness, which provides low sample sizes and statistical power to validate any community ecology theory. Additionally, most of the species-rich large herbivore assemblages in India inhabit forested habitats, which has made it difficult to study these large herbivore assemblages in India. Therefore, there exists an information gap that needs to be filled. Kaziranga National Park (KNP) in the Brahmaputra floodplains provides an opportunity to examine the community ecology of mega- and meso-herbivores in an ecosystem subject to human pressure and susceptible to

climate change. Thus, the present study was conducted in KNP and focused on six large herbivores (SLH) of different body sizes, specifically three mega-herbivores ─ Greater one-horned rhino (*Rhinoceros unicornis*), Asian elephant (*Elephas maximus*) and Asiatic wild buffalo (*Bubalus arnee*), and three meso-herbivores ─ swamp deer (*Rucervus duvaucelii*), hog deer (*Axis porcinus*) and sambar (*Rusa unicolor*). The study aimed a) to examine the diet composition of six sympatric large herbivores (greater one-horned rhinoceros, Asian elephant, Asiatic wild buffalo, swamp deer, hog deer and sambar) in KNP in terms of forage species and their quantity consumed; b) to determine the food preference and compare the seasonal diet overlap among the study species; and c) to determine the seasonal nutrient content and variation in the utilization pattern based on the nutrient quality of the major forage utilized by the six study species.

2. KNP, in the north-eastern Indian state of Assam, is situated in the floodplains of the Brahmaputra River, which runs along the northern boundary of the Park; and the Karbi Anglong Hills form the southern boundary. KNP covers an area of 429.93 km^2. An effort to conserve the rhino started with the notification of Kaziranga as a Reserve Forest in 1908. It was later notified as a Wildlife Sanctuary in 1950 and upgraded to a National Park in 1974. Subsequently, it was declared a UNESCO World Heritage Site in 1985, an Elephant Reserve in 2003 (Kaziranga – Karbi Anglong Elephant Reserve) and a Tiger Reserve in 2007. KNP, with its flat terrain and rich alluvial soil, is characterized by numerous permanent water bodies, locally known as *beels*. The climate is of the typical subtropical monsoon type. Floods from the Brahmaputra River play a crucial role in the maintenance of the wet grassland ecosystem in KNP, which largely constitutes of tall grasses, short grasses, wetlands and semi-evergreen forests, that supports the world's largest population of rhino and buffalo, and significant populations of the Eastern swamp deer and elephant. KNP is home to eight mega- and meso-herbivores *viz., R. unicornis, E. maximus, B. arnee, Bos gaurus, R. duvaucelii, A. porcinus, R. unicolor* and *Muntiacus muntjak*. Habitat fragmentation, poaching, flood, accident, zoonotic disease, dog kill, burning and overgrazing are key threats to the wild herbivore population in KNP.
3. The diet composition was assessed using the micro-histological technique, for which fresh faecal samples of mega- and meso-herbivores were collected each month from

November 2013 to April 2015 (excluding the flood period from June till October, during which the Park remains closed and the sample collection was not possible). Based on feeding signs and literature, 75 reference plant materials were collected. A bipartite ecological network was used to visualize the diet composition of mega- and meso-herbivores. Results revealed that both mega- and meso-herbivores were grazers and mixed feeders, as they consumed more than 50% of monocots. Compared to the dry season, these herbivores consumed more monocots in the wet season. From the dry to the wet season, elephant and sambar shift their diet from browsing to grazing. Irrespective of season, grasses contributed the most to the diet of SLH. Forage plants belonging to Poaceae and Cyperaceae families contributed more than 50% to the diet of mega- and meso-herbivores. From the dry to the wet season, SLH increased the consumption of forage plants belonging to Poaceae and Cyperaceae. Overall, 25 forage plants constituted more than 70% of their diet. Among monocots, family Poaceae with *Saccharum* spp. (contributing >9% of the diet), and, among dicots, family Rhamnaceae with *Ziziphus jujuba* (contributing >4% of the diet) fulfilled the dietary needs.

4. Herbivore forage utilization was quantified from faecal samples (N=1975) using micro-histological analysis, forage availability was quantified using the harvest method, and herbivores' preference by Jacob's index. Dietary similarities and dissimilarities among herbivores were estimated using Schoener Index, NMDS, ANOSIM and SIMPER. Results revealed that compared to the dry season (1354.54±641.30 gm^{-2}), significantly higher mean biomass was recorded in the wet season (3026.93±1632.65 gm^{-2}; $p<0.05$). Grasses contributed the most to biomass. Dicot was the most preferred forage of elephant, and monocot of swamp deer and sambar. From the dry to the wet season, rhino, buffalo and hog deer shift their preferred forage from dicot to monocot. Invasives *Merremia umbellata* and *Mimosa* spp. were avoided by SLH, and *Mikania micrantha* by meso-herbivores. Among SLH, a high dietary overlap was recorded between buffalo and hog deer (0.79-0.86), and swamp deer and hog deer (0.75-0.86), among mega-herbivores between rhino and buffalo (0.80-0.83), and among meso-herbivores between swamp deer and hog deer (0.75-0.86). Among SLH, high dietary dissimilarity was recorded between elephant and swamp deer (36-37%), among mega-herbivores between elephant and

buffalo (27-33%), and among meso-herbivores between swamp deer and sambar (27-29%).

5. The nutritional value of 17 major forage species consumed by SLH was examined. The samples were collected twice every month from November 2015 to May 2016, oven-dried and analyzed. For laboratory analysis, standard methods were used to estimate crude protein (CP), ash content (AC), fibre [neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL)], and minerals [Calcium (Ca), Phosphorous (P), Sodium (Na) and Magnesium (Mg)]. Results revealed that significant seasonal differences in AC, CP, ADL, Na, K and P content were found only for monocots. Between the dry and wet seasons, *Saccharum* spp. (monocot contributing >9% to SLH diet), showed significant differences in AC, CP, ADL and K concentrations, and *Ziziphus jujuba* (dicot contributing >4% to SLH diet) showed a significant difference only in ADL concentration. CP, ADL, NDF, Ca, Na and P concentrations varied significantly between monocots and dicots. In the dry season, the concentrations of CP, NDF, Ca, Na and P, and in the wet season, the concentrations of Ca and Na varied significantly between monocot and dicot. The results revealed that ADL concentration influenced forage use by SLH in the dry season, excluding elephants, whose forage use was influenced by NDF concentration. AC and ADL concentrations influenced the major forage use by SLH in the wet season.
6. In conclusion, both mega- and meso-herbivores consumed a more graze-based diet in the wet season than in the dry season. Possibly due to the availability of higher quality monocots in the wet season, both mega- and meso-herbivores consumed them in high proportion. Compared to other herbivores, the diet of the rhino, elephant and sambar consisted more of browse. This can be attributed to forage and habitat availability, predation risk, seasonal floods, and management practices such as controlled burning of the grasslands. From the dry to the wet season, probably due to precipitation, there is a significant increase in forage biomass, which also contributes to the forage preference of herbivores. The availability of invasives throughout the year, specifically *Merremia umbellata*, *Mimosa* spp. and *Mikania micrantha* have the potential to impact the foraging ecology of SLH. Irrespective of season, biologically significant dietary overlap (>0.6) was recorded among SLH.

This is attributed to sufficient forage availability and possibly to differences in foraging strategies and resource segregation at a spatio-temporal scale. Forage segregation, despite being challenging to interpret at the taxonomic level, influences niche partitioning among mega- and meso-herbivores. Throughout the year and in the dry and wet seasons, dicots with high CP and mineral concentrations were more nutritious than monocots. Whereas in the wet season, monocots were nutritious and highly digestible. Forage selection by mega- and meso-herbivores can be predicted based on the AC, ADL and NDF content. In KNP, the ongoing processes of succession and invasion threaten the grasslands, which in the future might affect the availability of the principal forage plants consumed by mega- and meso-herbivores. Therefore, to maintain the herbivores' population in KNP, it is crucial to retain the integrity of grassland and formulate effective plant-specific management plans that fulfil their dietary needs. Formulating a conservation management plan requires baseline information on the species inhabiting the area. In the climate crisis and habitat degradation era, the present study will help Park managers to formulate a) effective herbivore species-specific conservation action plans; b) conservation strategies that need to address the feeding ecology of the large herbivores; and c) strategies to improve herbivore species-specific relocation programmes.

CHAPTER 1
INTRODUCTION

1.1 Background

Ecology has played a crucial role in revealing the morphology, physiology, behaviour, population dynamics, and interactions of species at different trophic levels (Chase, 1996). Interactions occurring at different trophic levels include the prey-predator mechanism wherein top predators consume their prey and limit their numbers, affecting the lower trophic level, which is known as the "Trophic Cascade" (Sih et al., 1985; Chase, 1996). In herbivore-plant interactions, the herbivores influence the plant communities (a) directly, through trophic pathways, by acting as plant predators via feeding on them and influencing their host plants' population dynamics (Marquis, 2010; Wardle, 2010); and (b) indirectly, through non-trophic pathways, by acting as ecosystem engineers via digging, trampling, seed-eating, rooting, nest building, and deposition of faeces (McNaughton et al., 1997; Polley & Collins, 1984; Wilby et al., 2001; Ickes et al., 2001; Pringle, 2008; Marquis, 2010). In terrestrial ecosystems, herbivores' abundance is affected by natural and anthropogenic pressures (Bakker et al., 2006). Marquis (2010) suggested that plant distribution, availability and susceptibility to herbivores and parasites influence the abundance and distribution of herbivores. Conversely, with their varied body sizes, herbivores affect plant diversity through population density, feeding ecology and mobility, which also affects the susceptibility of these herbivores to trophic control. These trophic dynamics can be better understood with information on the feeding ecology of herbivores in terms of their feeding habits, resource partition, forage preference, and nutritional quality of important forage species. Additionally, knowledge and understanding of the feeding ecology of herbivores help in their management, as it requires knowledge of how herbivores utilize the resources available to them (Nelson & Leege, 1982).

1.2 Feeding Ecology of Herbivores

Various theories and explanations have helped in understanding the community and foraging ecology of large bodied mega-herbivores (>1000 kg) to medium bodied meso-herbivores (>5 kg and <500 kg). Niche and resource partitioning play an important role in the coexistence of sympatric species occurring in the same area, not necessarily in the same niche, termed as sympatric species (Odum, 1971; Sankar, 1994). The ecological succession and separation theory described forage resource partitioning as the reason for the coexistence of herbivores of different body sizes (Vesey-FitzGerald, 1960; Lamprey, 1963; Bell, 1970). Resource-utilization concept suggests that two species cannot occupy a similar niche in a similar environment over long time scales without showing competition, which might result in the local extinction of other species (Hardin, 1960; MacArthur & Levins, 1967). In contrast, ecological niche partitioning, one of the fundamental principles used in community ecology, predicts that sympatrically occurring species partition their resources spatially or temporally to coexist without competition (Pianka, 1969; Schoener, 1974; Azevedo et al., 2006; Chillo et al., 2010). The coexisting species are expected to show natural selection by evolving themselves for niche partition in limited resource conditions (MacArthur & Levins, 1967). The knowledge and understanding of resource selection and partitioning is integral to understanding large herbivore prey (plant) predator (herbivore) dynamics (Marquis, 2010).

Hofmann and Stewart (1972) cited digestive physiology as the explanation for the difference in foraging style, whereas Bell (1970) and Jarman (1974) explained the coexistence of mega- and meso-herbivores as a function of both body mass and digestive physiology. The Jarman-Bell principle emphasizes that the quality and quantity of large herbivores' diet correlates with their body size; specifically, the diet quality decreases as body size increases. Depending on body size, herbivores consume a large or small amount of coarse forage to fulfil their body requirement (Bell, 1971; Jarman, 1974). The allometric theory (Kleiber, 1932) explained, while Demment & Van Soest (1985) provided the evidence of the mechanism behind the Jarman-Bell principle. The allometric theory explains that the length of the digestive tract is directly proportional to the body mass, and consequently, the metabolism rate is inversely proportional to the body mass (Kleiber, 1932). This suggests that species with small body sizes have higher metabolic rates and energy requirements than those with large body sizes; hence they are more dependent on the quality of forage they feed (Belovsky, 1997). Species with large body sizes extract energy from larger portions of a low-quality forage and are able to tolerate low-quality forage. Demment and Van Soest (1985) provided evidence that the capability to digest coarse forage increases with the increase in gut capacity. Hence, the digestive capability of mega- and meso-herbivores plays a crucial role in their dietary selection (Hofmann, 1973; Ahrestani et al., 2016). Thus, depending on both nutritional (crude protein content, mineral content and digestibility) and anti-nutritional parameters (plant secondary metabolites and fibre), meso-herbivores need to browse on forage with high protein and low fibre content. In contrast, mega-herbivores may feed on forage with low protein and high fibre content (Geist, 1974; Clauss et al., 2013).

Among large herbivores, the forage availability, quality, and body mass have been the cornerstone of understanding foraging ecology (Ahrestani, 2009). Both the dry and wet seasons govern the change in forage availability and quality that challenge the herbivores to fulfil their energy requirement (Prins & Loth, 1988; Putman, 1988; Owen-Smith, 1988). In temperate regions, forage availability is high during summers (Ahrestani, 2009); while in tropical areas, forage availability is high during the wet season. Although, in areas where resource availability varies seasonally, the forage selection by herbivores varies both temporally and spatially (Kleynhans et al., 2011).

Davidson (1993) suggested that the feeding choices of herbivores for early- or late-successional plant species affect the process of succession either by accelerating or moderating it. Experimental studies have shown that removing herbivores from the ecosystem can change plant species composition and communities (Marquis, 2010). Based on their body size, herbivores influence the vegetation structure through coarse and soft feeding (Marquis, 2010). Milchunas and Lauenroth (1993) demonstrated that mega-herbivores with large body sizes (>1000 kg) required more forage in less time and were less selective, feeding more on dominant species, and consequently, increasing plant diversity. In contrast, Edward and Crawley (1999) demonstrated that meso-herbivores with medium body size (>5 kg and <500 kg) required qualitative forage and were more selective, feeding on more nutrient-rich species, and consequently, decreasing plant diversity. Comparatively, meso-herbivores are more selective in their feeding choices and act as soft feeders, whereas the less selective mega-herbivores act as coarse feeders (Owen-Smith, 1988; Edward & Crawley, 1999).

Studies carried out in Africa showed that the experimental removal of herbivores affected the vegetation of the area, and revealed the potential of herbivores to convert woodlands into grasslands (Sinclair, 1995; Augustine & McNaughton, 1998; Marquis, 2010). The study by Hartvigsen and McNaughton (1995) in the Serengeti grasslands demonstrated that the intensively grazed areas had the highest number of short and fast-growing plant species; in contrast, the lesser grazed areas had a higher number of taller and slower-growing plant species. Therefore, depending on the herbivore's abundance, feeding choices, and the trade-off between plant species, they can influence the plant species richness (Lubchenco, 1978; Marquis, 2010).

Forage quality is associated with the growth stage of the forage and environmental factors such as temperature, soil type and precipitation. In tropical areas, the forage is more nutritious in the wet season with low fibre and high nutrient content, whereas, it is less nutritious in the dry season with a high carbon-to-nitrogen ratio (Prins & Loth, 1988; Styles & Skinner, 1997; Hopkins, 2000). Therefore, in tropical areas, meeting the nutritional requirements is more arduous for the herbivores in the dry season than in the wet season. In temperate regions, wild ruminants endure dramatic seasonal changes in nutrient flux due to circannual rhythms in forage quality, intake, reproduction and metabolism (Moen, 1978). Plant growth and temporal distribution of forage resources play a vital role in shaping the diet of herbivores.

Forage quality also depends on the ratio of nutritional and anti-nutritional parameters. Anti-nutritional parameters have the potential to reduce the digestibility of nutritional parameters (Uniyal et al., 2005). Browse species, when compared to graze species, have higher levels of soluble cell content and nitrogen, which are beneficial for large herbivores, but at the same time also have higher levels of lignin and secondary metabolites, which are detrimental to large herbivores (Demment & Van Soest, 1985; Duncan & Poppi, 2008; Ahrestani et al., 2016). Differences in nutrient parameters of graze and browse species have led to different adaptations in animals specializing in one or the other plant type, with implications for all aspects of their ecology and life history (Hofmann & Stewart 1972; Hofmann 1973 & 1989; Gordon 2003; Duncan & Poppi 2008).

In India, terrestrial ecosystems are shared by multispecies assemblages of terrestrial mammalian herbivores of diverse body sizes, from the mouse deer (2-4 kg) to the Asian elephant (3000-5400 kg) (Devi et al., 2022a). Still, how these multispecies systems persist without conflict and what mechanisms facilitate the stable coexistence of many similar species is understudied (Ahrestani, 2009). The Brahmaputra floodplains of North-east India, with their dynamic riverine alluvial grassland ecosystem, support the high biological diversity of herbivores. These riverine alluvial grasslands are home to the largest remaining population of the Greater one-horned rhino (*Rhinoceros unicornis*), Asiatic wild buffalo (*Bubalus arnee*) and swamp deer (*Rucervus duvaucelii*). The knowledge and understanding of the community ecology of mega- and meso-herbivores is crucial for the effective management of herbivores and their associated habitat.

Kaziranga National Park (KNP) in the Brahmaputra floodplains of the Indian state of Assam is the only remaining habitat that supports sympatrically occurring eight large herbivores species of different body sizes, specifically four mega-herbivores viz., Greater one-horned rhino, Asian elephant (*Elephas maximus*), Asiatic wild buffalo and gaur (*Bos gaurus*), and four meso-herbivores viz., swamp deer, hog deer (*Axis porcinus*), sambar (*Rusa unicolor*) and barking deer (*Muntiacus muntjac*). KNP provides the opportunity to study the community ecology of coexisting large herbivores in an ecosystem that is subjected to anthropogenic pressures and is vulnerable to climate change. Habitat fragmentation, poaching, floods, burning, biological invasion and disease are some of the major threats to the wild herbivores in KNP. Evaluation of the foraging ecology of these large herbivores in terms of dietary patterns, and forage availability and quality are essential in understanding their community ecology in a grassland ecosystem and formulating species-specific management plans.

1.3 Literature Review

Africa with 94 ungulate species, represents the highest species richness among all the continents (Wilson & Reeder, 2005; Ahrestani & Sankaran, 2016). South and South-

East Asia is represented by 83 ungulate species and 19 terrestrial mammalian herbivore species with a body mass greater than 100 kg (Ahrestani, 2009; Ahrestani & Sankaran, 2016). The herbivore species found in India are distinct from those in Africa, similar only in the diverse range of body sizes, from mega-herbivores to meso-herbivores, and the presence of hindgut and foregut fermenter species (Devi et al., 2022a). India is represented by 39 ungulate species (Prater, 1985; Wilson & Reeder, 2005) and 14 terrestrial herbivores with a body mass more than 100 kg (Ahrestani, 2009). Of these 14 terrestrial mammalian large herbivores in India, nine are listed under the IUCN red list category of Rare, Endangered and Threatened (RET) fauna. Five of these 14 largest mammalian herbivores exist in KNP viz., Greater one-horned rhino, Asian elephant, Asiatic wild buffalo, swamp deer, sambar (Ripple et al., 2015). Hunting, poaching, habitat degradation and competition with domestic herbivores jeopardize their existence in the wild (Ripple et al., 2015).

Most studies that studied large herbivores' community ecology have emerged from Africa, Europe and North America. Limited scientific studies have provided a detailed account of forage preferences and overlap in the diet of large herbivores in South Asia (Ahrestani et al., 2012), especially for Greater one-horned rhino, Asian elephant, Asiatic wild buffalo, swamp deer, hog deer, and sambar. Despite harbouring diverse large herbivore species, India has contributed little to the science of large herbivores' foraging ecology at the community level. One of the reasons behind this is that large herbivore assemblages in India have low species richness, providing low sample sizes and statistical power to validate community ecology theories (Ahrestani, 2009; Ahrestani et al., 2012).

1.3.1 Diet composition

The Greater one-horned rhino population is restricted to the riverine alluvial grasslands in select protected areas of India and Nepal (Ahrestani et al., 2016). Due to their limited distribution, there are very few studies on the ecology of these rhinos. In Nepal, Laurie (1982) conducted a study on the ecology of rhinos in Chitwan National Park (CNP) and identified 183 forage species belonging to 57 families in the rhino diet. Jnawali (1995) identified 283 forage species from CNP and 179 forage species from Bardia National Park (BNP) in the rhino diet. Similarly, in India, Patar (1977) conducted a study on the feeding habits of rhinos in KNP and identified 47 forage species in their diet. Konwar et al. (2009) identified 32 forage species in the rhino diet from Pobitora Wildlife Sanctuary (PWLS) and also revealed that grass formed a major portion of the rhino diet. Bhatta (2011) identified 163 forage species in the rhino diet in PWLS. Hazarika and Saikia (2012) identified 138 forage species in the rhino diet from Rajiv Gandhi Orang National Park (RGONP) and revealed that grass formed a major portion of the rhino diet. Dutta et al. (2016) identified 139 forage species belonging to 39 families in the rhino diet from Manas National Park (MNP) and found that a major portion of the rhino diet constituted of grasses (24%).

Asian elephants act as roughage feeders and feed on a wide variety of forage species to fulfil their body requirements (Ahrestani et al., 2016). Elephants are hindgut fermenters with short digestion passage rates, which helps them tolerate high roughage levels (Ahrestani et al., 2016). Studies conducted in different parts of Asia have revealed the grazing feeding behaviour in Asian elephants, particularly in Sri Lanka (Mckay, 1973; Vancuylenberg, 1977), China (Olivier, 1978) and India (Sivaganesan & Johnsingh, 1995; Borah & Deka, 2008). Sukumar (1990) studied the ecology of the Asian elephant in southern India and identified 112 forage species, and revealed that the elephant diet composed more of a browse-based diet during the dry season and graze-based during the wet season. Datye (1995) conducted a study in Dalma Wildlife Sanctuary, India, and identified 54 forage species in the Asian elephant's diet, of which 33 were dicots and 21 monocots. Tiwari (2000) identified 37 forage species belonging to five families in the diet of Asian elephants in Chandaka Wildlife Sanctuary, India. Chen et al. (2006) identified 106 forage species in the Asian elephant diet from Shangyong National Nature Reserve, China. Baskaran et al. (2010) studied the feeding ecology of the Asian elephant in the Nilgiri Biosphere Reserve, India, and identified 88 forage species in the elephant diet, of which 59 were identified as browse species, and 29 as graze species. The study also revealed that grass constitutes a major proportion of the elephant diet in the wet season compared to the dry season. Sarkar et al. (2012) identified 46 forage species belonging to 26 families in the diet of Asian elephants from Kameng Elephant Reserve, India. The study also revealed that *Calamus* sp. was a majorly consumed species. In Nepal, Koirala et al. (2016) identified 40 and 37 forage species in the Asian elephant diet in Parsa Wildlife Reserve (PWLR) and CNP, respectively.

The Asiatic wild buffalo is one of the least studied species in terms of feeding ecology (Ahrestani et al., 2016). The comparable information available for this species is primarily based on the domestic buffalo (*Bubalus bubalis*), which primarily acts as a grazer (Ahrestani et al., 2016). Bawri and Saikia (2014) conducted a study on the feeding ecology of Asiatic wild buffalo in KNP and found that buffalo foraged on 183 forage species belonging to 47 families, and grass formed a major portion of the diet. Shrestha et al. (2020) conducted a study in Koshi Tappu Wildlife Reserve, Nepal, on the nutritional parameters of forage species preferred by wild water buffalo and identified 54 forage species in their diet and concluded that buffalo feed on a wide variety of forage species to fulfil their nutritional requirements.

Swamp deer is endemic to the Indian subcontinent and is associated with the swampy habitat where they feed primarily on grasses, aquatic shrubs, forbs and sedges (Ahrestani et al., 2016). Schaller (1967) conducted a study in Kanha National Park and identified 13 forage species in the swamp deer diet. Wegge et al. (2006) identified 18 forage species in the diet of swamp deer from BNP, Nepal and found that 13 grass species constituted a major portion of the diet. Tewari and Rawat (2013) identified 42 forage species belonging to 15 families in the swamp deer diet from Jhilmil Jheel Conservation Reserve, India. Swamp deer act as a mixed feeder and graze more during the rainy season, when the availability of grasses is maximum (Ahrestani et al., 2016).

Hog deer inhabits open forest and feeds primarily on grasses during the wet season and switch their diet to browse during the dry season, presumably to fulfil the nutritional body requirements (Ahrestani et al., 2016). Wegge et al. (2006) identified 15 forage species in the diet of hog deer, of which nine grass species constituted the major portion. Tuboi and Hussain (2016) identified 18 forage species in the diet of hog deer from Keibul Lamjao National Park, India, and also concluded that grass formed a major portion of the diet. Compared to sambar, hog deer are more selective of the forage part they consume (Ahrestani et al., 2016).

Sambar is the largest deer in Southeast Asia and is among the most widely distributed large herbivores (Ahrestani et al., 2016). It inhabits diverse habitats, which might be responsible for its generalist feeding behaviour (Ahrestani et al., 2016). In most cases, when sambar inhabits forested areas with sparsely distributed grasses, they tend to involve themselves primarily in browsing (Ahrestani et al., 2016). Schaller (1967) observed sambar feeding on 12 forage species in Kanha National Park. A study conducted by Johnsingh and Shankar (1991) in the Mundanthurai plateau, India, reported sambar feeding on 139 forage species. A study by Padmalal et al. (2003) in Horton Plains National Park, Sri Lanka, revealed that sambar feeds more in grasslands during summers, and in forests during winter.

Literature review indicates that mega- and meso-herbivores act as grazers, browsers and mixed feeders, showing significant seasonal variation in consumed food items. However, little is known about the feeding habits of mega- and meso-herbivores from the riverine alluvial grasslands, where they still co-occur sympatrically.

1.3.2 Forage Preference and Dietary overlap

Understanding the niche of an animal is crucial for understanding the community dynamics of dependent consumers. Foraging is one of the fundamental elements of a niche that aids in making assumptions about the behaviour, physiology, morphology and population dynamics of herbivores. Based on preference for the two major plant types, monocots (grasses and sedges) and dicots (forbs, shrubs, and trees), herbivores are categorized as grazers (feed mainly on graminoids or monocots), browsers (feed mainly on browse or dicots), or mixed feeders (feed on both monocots and dicots, according to their availability) (Hofmann & Stewart 1972; Ahrestani et al., 2016). Any changes in the consumption of monocots (grazing) and dicots (browsing) result in changed diet compositions. Sympatric large herbivore species differ in diet composition, both by eating different parts of the same plant and by eating different plant species (Bell, 1971; Pansu et al., 2019). Thus, knowledge and information on the feeding habits of large herbivores with respect to preferences and overlap is crucial to understanding their ecology and essential for their management and conservation.

Forage availability influences the forage utilization patterns of Asian elephant and buffalo, as during the resource-limited dry season, when grass availability is extremely low, these herbivores consume dicots more than monocots (Pieris et al., 2011). Patar (1977) identified *Arundo donax*, *Hemarthria compressa* and *Erianthus elephantinus* as the grasses preferred by rhinos in KNP. Johnsingh and Sankar (1991) identified that in the forest areas of the Mundanthurai Plateau, herbs were the most preferred forage of sambar, followed by shrubs and grasses. Additionally, they also recorded a significant dietary overlap between chital and sambar (73%). Santra and Gendley (2014) found that in the forested area of southwest Bengal, the migratory elephants prefer to feed more on the nutrient-rich forage species. With mixed feeding behaviour, elephants tend to change their forage utilization and forage preference. Koirala et al. (2016) identified 26 preferred forage species in the diet of the Asian elephant in a study conducted in PWLR and CNP. Ahrestani et al. (2012) studied the feeding ecology of the chital, sambar, gaur and Asian elephant in Bandipur and Mudumalai, South India, where they found that chital grazes more in the wet season, although browse also formed a major portion of the diet in the dry season. The study also concluded that gaur preferred to graze, sambar preferred to browse, and Asian elephant was mixed feeder throughout the year.

The pioneer studies conducted by Lamprey (1963) on sympatrically occurring 14 ungulate species in Tanganyika Game Reserve in Africa and Hirst (1975) on seven sympatrically occurring ungulate species in the savannas of South Africa revealed that each species had its own niche, and competition was avoided at the spatial and temporal scale. The studies conducted by Field and Laws (1970), Blankenship and Field (1972) and Jarman (1974) provided evidence of different feeding styles used by large sympatric herbivores. Scogings et al. (1990) conducted a study in South Africa on the habitat use of 10 sympatrically occurring ungulate species, ranging from impala to zebra, and revealed that each ungulate species avoided competition by utilizing various habitat components.

The literature available to understand the science of wild large herbivore foraging ecology at the community level is limited from India (Wegge et al., 2006). Most of the research conducted in India studied up to four wild herbivore species and contributed mostly to their biology and ecology (Wegge et al., 2006; Ahrestani, 2009; Devi et al., 2022a). The limited information that is available is from Kanha National Park (Schaller, 1967; Martin 1982), Kedarnath Sanctuary (Green,1987), Mundanthurai Plateau (Johnsingh & Sankar, 1991), Sariska Tiger Reserve (Sankar, 1994), Ranthambhore National Park (Bagchi et al., 2003), and Mudumalai and Bandipur Tiger Reserves (Ahrestani, 2009).

Martin (1982) studied the interspecific relationship in terms of forage and overlap between swamp deer and chital in Kanha National Park. Green (1987) studied the interspecific competition among four Himalayan ungulates viz., Himalayan musk deer, sambar, serow and goral; Johnsingh and Sankar (1991) studied among three ungulate species, namely chital, sambar and cattle; Sankar (1994) studied among three ungulate species viz., chital, sambar and nilgai; Bagchi et al. (2003) studied among four sympatric ungulates viz., chital, sambar, chinkara, and nilgai; and Ahrestani (2009) studied among four sympatric ungulates, namely chital, sambar, gaur and Asian elephant.

The literature review suggests that little is known about the degree of determinants of inter- and intra-specific diet variation among the six large herbivore species, three mega-herbivores viz., Greater one-horned rhino, Asian elephant, Asiatic wild buffalo, and three meso-herbivores viz., swamp deer, hog deer and sambar. One of the justifications for this might be that in most parts of the world, rhinos and buffalo no longer coexist with elephants, swamp deer, hog deer and sambar (Pradhan et al., 2008). Therefore, little is known about their inter- and intra-specific diet variation and its impact on the vegetation structure at the landscape level. Most of the studies on resource partitioning among and between large herbivores, including rhino, Asian elephant, swamp deer and hog deer, have emerged from BNP in Nepal (Steinheim et al., 2005; Wegge et al., 2006; Pradhan et al., 2008). In the riverine alluvial grasslands of Nepal (BNP), Wegge et al. (2006) identified a significant dietary overlap among Greater one-horned rhino, swamp deer and hog deer in the resource-limited dry season. Pradhan et al. (2008) also reported a high dietary overlap between Greater one-horned rhino and Asian elephant during the monsoon season (resource-rich) and low during the dry season (resource-limited). During resource-limited seasons, forage segregation between the species can be better understood by forage utilization at a spatio-temporal scale (Pradhan et al., 2008). Suggesting that resource availability and utilization by herbivores are important indicators to predict resource segregation among large herbivores.

1.3.3 Forage Nutrient Quality

Forage quality is one of the important determining factors of herbivores' forage utilization and selection. The amount of energy and nutrients consumed influences herbivores' survival and reproduction rate (Ahrestani et al., 2012). For herbivores, the growth phase, structure and phenology, and seasonal availability of the forage species are crucial, which are impacted by management interventions like grassland burning (Banerjee, 2001). Nitrogen concentration and digestibility of forage species is highest during the early growth stage. As the growth stage of forage species progresses, Nitrogen concentration decreases and structural components increase, which reduces the digestibility and quality of forage (Banerjee, 2001). Understanding the physico-chemical properties of forage species is crucial to interpret the nutritional aspects and availability of quality forage.

Bell (1970) and Jarman (1974) proposed that with an increase in body size, the ability of the animal species to feed on more coarse forage species also increases. The preponderance of the studies that examined the ecology of large assemblages of sympatric herbivores and tested the Jarman–Bell principle have primarily emerged from Africa and North America (Pradhan et al., 2008; Ahrestani et al., 2012). The studies conducted to test the Jarman–Bell principle in the African savannas (McNaughton & Georgiadis, 1986; Owen-Smith, 2002; Fryxell, 2005; Bailey & Provenza, 2008; Prins & Langevelde, 2008) and the protected areas of North America (Olff et al., 2002) primarily covered dry tropical grasslands, forests, or savannas. In Asia, Wegge et al. (2006) and Ahrestani et al. (2009) tested the Jarman–Bell principle in Nepal and India.

Grzimek and Grzimek (1960) conducted a study in the Serengeti plains and found that neither all areas nor all grass species were equally used by ungulates. Kar-Gupta and Kumar (1991) revealed that crude protein and fibre content of forage influenced forage selection among herbivores. Putman (1996) revealed that ungulates preferred highly digestible forage species rich in protein, which is strongly affected by season. A study conducted by Banerjee (2001) in KNP revealed that during the winter season, short grasslands showed more crude protein content, whereas, during summer, tall grasslands showed more crude protein content; suggesting that in the wet season, tall grasslands are more nutritious than short grasslands. The study also revealed that while rhino and hog deer utilized habitat rich in crude protein and low in ash content, the Asiatic wild buffalo and swamp deer utilized habitat rich in crude protein with a medium level of ash content. Rhino with hindgut fermentation and Asiatic wild buffalo with foregut fermentation feed on high crude protein and high fibre content, respectively. A study by Codron et al. (2007) on the nutritional content of forage utilized by ungulates in Kruger National Park, South Africa, revealed that dicots showed high Nitrogen content and low NDF and ADF content compared to monocots. A study conducted by Borah and Deka (2008) in Rani Range Forest, India, found that the diet of Asian elephants constituted of the forage species rich in fibre. Robbins (2012) also suggested that herbivores feed on forage rich in protein to meet their body requirement. A study in Bandhavgarh Tiger Reserve, India, by Sankar et al. (2015) revealed that gaur spend less time feeding in low-nutrient areas, and grasses with high crude protein were more nutritious in the wet season.

1.4 Justification of the Study

Studies that examined the community ecology, resource partition, competition and habitat utilization among large assemblages of sympatric herbivores along temporal and spatial scales have primarily emerged from Africa, Europe and North America (Ahrestani, 2009). Most of the species-rich large herbivore assemblages in Asia inhabit forested habitats, which makes it difficult to study these animals in Asia. India, with diverse assemblages of large herbivore species, has contributed very little to the science of their foraging ecology at a community level. Despite the numerous studies on dietary patterns, nutrient parameters and ungulate coexistence mechanisms, understanding niche segregation in terms of forage species consumed by large herbivore guilds remains unclear. It is because large herbivore assemblages in India have low species richness, providing low sample sizes and statistical power to validate community ecology theories (Ahrestani et al., 2012). In most parts of the world, rhinos and buffalo no longer coexist with elephants, swamp deer, hog deer and sambar (Pradhan et al., 2008). Therefore, little is known about the degree of determinants of inter- and intra-specific diet variation among these six large herbivores (henceforth, referred to as SLH). Although many studies provide information on the dietary patterns of SLH in terms of growth forms, monocots (graze) and dicots (browse), or stable carbon isotopes (Sankar, 1994; Pradhan et al., 2008; Ahrestani, 2009), providing comparative quantification of diet from these studies is difficult as they are unlikely to be informative. This study quantifies and compares the dietary patterns of SLH in terms of monocot & dicot, growth forms, families and forage species consumed.

1.5 Objectives

The study aimed to examine the feeding habits of sympatric SLH in KNP and the strategy they adopt for optimum resource utilization. Keeping in view the above background, the following objectives were set forth for the present study:

1) To examine the diet composition of six sympatric large herbivores (Greater one-horned rhino, Asian elephant, Asiatic wild buffalo, swamp deer, hog deer and sambar) in KNP in terms of forage species and their quantity consumed.

2) To determine the food preference and compare the seasonal diet overlap among study species.

3) To determine the seasonal nutrient content and variation in the utilization pattern based on the nutrient quality of the major forage utilized by six study species.

1.6 Key Questions

The study aims to answer the following research questions:

1) Is there any difference in the diet composition of SLH in each season in terms of:

a) monocot and dicot
b) six categories of growth form viz., grasses, sedges, herbs, shrubs, climbers and trees
c) forage species contributing to the diet.

2) What are the most selective forage species in the diet of SLH in the dry and wet seasons?
3) What is the similarity and dissimilarity in SLH diet, and which forage species contribute the most to diet dissimilarity?
4) What is the seasonal nutrient content of major forage species consumed by SLH?
5) Is seasonal variation in the nutrient content responsible for the variation in the seasonal utilization of major forage species by SLH?

1.7 Organization of thesis

The thesis is organized into seven chapters. After a brief introduction in chapter 1, the study area has been described in chapter 2, followed by study species distribution, population status and conservation history in chapter 3. The food habits and composition of the diet of SLH have been described in chapter 4, forage availability, preference and diet overlap among the six study species in chapter 5, and the nutritional quality of major forage species utilized by the six study species in chapter 6. At the end of chapter 7, synthesis, conservation implications and management recommendations have been presented with a general discussion regarding conservation strategy and management of herbivores in KNP.

CHAPTER 2
STUDY AREA

The study was carried out in the Kaziranga National Park (KNP) from 2013 to 2016 (excluding the flood period from June to October). KNP in the north-eastern Indian state of Assam is situated in the floodplains of the Brahmaputra River, which runs along the Park’s northern boundary, with the Karbi Anglong Hills forming the southern boundary. With an area of 429.93 km^2, KNP extends between latitudes 26°34’N to 26°46’N and longitudes 93°08’E to 93^{0}36’E and represents the single largest Protected Area within the Brahmaputra valley (Figure 2.1). According to Rodgers and Panwar (1992), KNP falls in the North-East India biogeographic zone and Brahmaputra Valley biotic province (9A). Kaziranga harbours the largest remaining population of the Greater one-horned rhino and is renowned worldwide for its success in the conservation of the species.

2.1 Conservation History

Kaziranga was first declared a Reserve Forest in 1908, later upgraded to Game Sanctuary in 1916, a Wildlife Sanctuary in 1950, and a National Park in 1974. Subsequently, it was declared a UNESCO World Heritage Site (1985) and a Tiger Reserve (2007). After more than 100 years of conservation efforts, the population of wildlife in the area has increased (Devi et al., 2022a). Administratively, Kaziranga Tiger Reserve (KTR) has been divided into five different ranges, namely i) Kohora (Central), ii) Bagori (Western), iii) Ghorakati (Burapahar), iv) Agoratoli (Eastern), and v) Biswanathghat (Northern). The present study was restricted to only three ranges, Kohora, Bagori, and Agoratoli ranges.

2.2 Terrain, Geology and Soil

The terrain of KNP is flat, with a gentle, almost imperceptible slope from east to west and north to south. The Karbi-Anglong hills in the south surround KNP. Along the Karbi-Anglong boundary, the Kukurakata Reserve Forest, with hilly, and the Panbari Reserve Forest, with both flat and hilly slopes, are present. KNP is characterized by scattered water bodies, locally known as '*beels*', which are generally formed by the changing course of the tributaries of the Brahmaputra River. These *beels* not only support the animals in the area by fulfilling their water requirement for drinking and wallowing, but also support the short grasslands, which are an important foraging ground for wild herbivores in the area (Laurie, 1978).

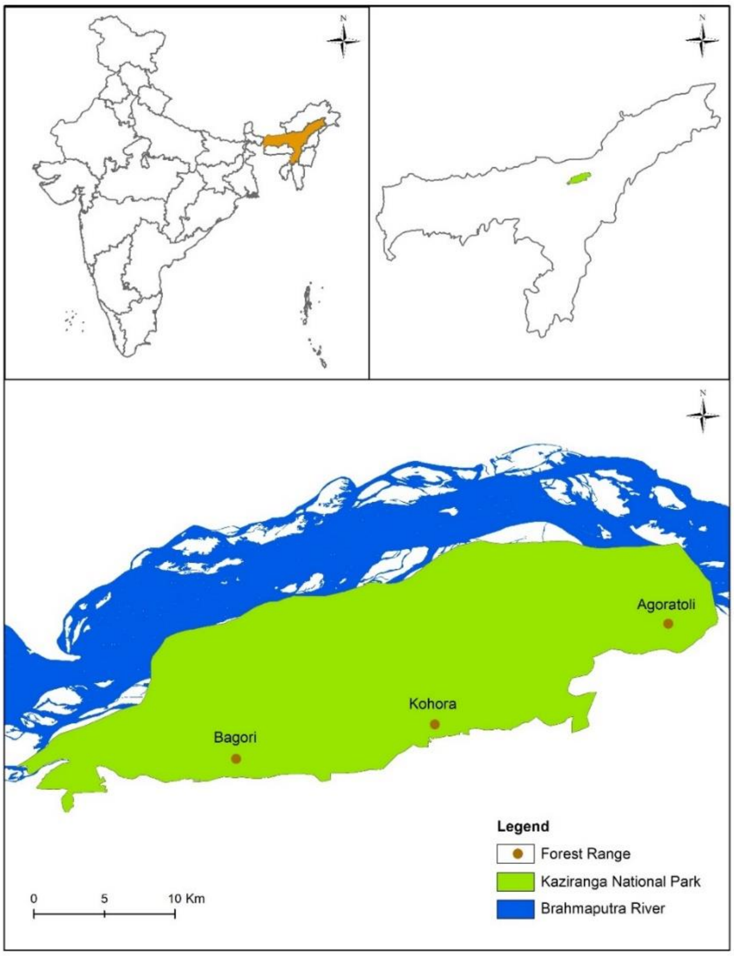


Figure 2.1 Location of the study area showing Kaziranga National Park, Assam.

From a lithological point of view, Kaziranga has a rich deposit of alluvial soil brought by annual floods, constituting of grey silt and fine to medium sand, which forms the recent composite floodplain with numerous meander scars and scrolls, palaeochannels and abandoned channels belonging to the Holocene phase of quaternary ages (Vasu and Singh, 2015). Older deposits of alluvium date back to the Pleistocene period and consist of sand, pebbles, clay and silt with the formation of impure calcium carbonate. In the elevated areas, the older alluvium deposits are relatively unaffected by the flood.

Alluvium of new origin is of light colour, and consists of sand, silt, clay and pebbles, and low calcium deposits (Banerjee, 2001). Soil deposition in KNP is heavily influenced by recurrent floods, which form the mosaic of clay soils and deposits of fresh sand in the topsoil. Therefore, the soil of KNP can be categorized into sandy soil, sandy loam, and clayey loam to pure clayey soil. Changes in the soil composition of the Park impact vegetation communities, which in turn influences grassland successional processes. Brahmaputra River exhibits a braided pattern with numerous river islands. Due to the changing pattern of the river, the left bank erodes a considerable stretch of the land along its banks, which severely affects the park landmass. KNP has two types of river islands, locally termed as *chaporis,* stable and unstable. The stable *chaporis* have a large extent and tall grass cover, whereas unstable islands are devoid of grass cover. The left bank of the Brahmaputra River, which forms the erstwhile northern boundary of the National Park, is very steep, and its height varies from 3 to 7m.

2.3 Climate

The climate of Kaziranga is typical subtropical monsoon type divided into dry (from October to March) and wet seasons (from April to September). From January 2014 to December 2015, the total annual precipitation in the KNP varied from 1630.4 to 2247.8 mm, with mean annual precipitation of 1939.1 ±308.7 mm. High precipitation was recorded in the wet season, which varied from 1557 to 2021.2 mm with mean precipitation of 1939.1 ±308.7 mm, and low precipitation in the dry season, which varied from 73.4 to 226.6 mm with mean precipitation of 150 ±76.6 mm. The maximum temperature ranged from 27 to 39 °C, and the minimum temperature ranged from 5 to 23 °C (2014-15, Assam Forest Department).

2.4 Flora and Fauna

2.4.1 Vegetation

KTR is a biodiversity hotspot located in the Indo-Malayan realm encompassing a variety of habitat types comprising of alluvial grasslands, divided into short and tall grass communities, interspersed by tropical moist deciduous to semi-evergreen forests. Champion and Seth (1968) described the grasslands of Kaziranga as “Eastern wet-alluvial grasslands”. Hajra (1978) classified the vegetation of Kaziranga into four broad categories: a) alluvial inundated grasslands, b) tropical semi-evergreen forest, c) tropical wet evergreen forest, and d) aquatic vegetation (Plate 1).

a) Alluvial inundated grasslands

The alluvial inundated grassland covers two-thirds of KNP and is categorized into tall and short grasslands, which dominate the Park compared to other habitats (Kushwaha & Unni, 1986). The west side of the Park is dominated by tall elephant grass (*Saccharum* spp.), and in short grasslands, the lower ground is mainly surrounded by short grasses and *beels*. A study conducted by Kushwaha (1997) reported that in KNP, 61.01% of the area was under tall grasslands dominated by *Saccharum* spp., *Phragmites karka*, *Arundo donax*, *Alpinia nigra*, *Imperata cylindrica*, *Chrysopogon zizanioides* and *Themeda arundiacea.* Short grassland, spread over only 3.01% of the area, was dominated by short grasses like *Cynodon dactylon*, *Hemarthria* spp., and *Cyperus* spp. Among families, Poaceae and Asteraceae dominate these grasslands.

b) Tropical Semi-evergreen forests

The tropical Semi-evergreen forests are dominated by *Albizia procera, Bombax ceiba, Trewia nudiflora, Ziziphus mauritiana, Lagerstroemia parviflora* and *Bridelia retusa*. These forests often support luxuriant and impenetrable thickets of cane (*Calamus* spp.).

c) Tropical wet evergreen forests

Tropical wet evergreen forests are chiefly unaffected by annual flooding and dominated by *Dillenia indica*, *Alstonia scholaris*, *Ficus* spp., *Garcinia tinctonia, Calamus tenuis, Syzygium cumini* and *Litsea nitida.*

d) Aquatic/ Semi aquatic vegetation

The grasslands and woodlands are interspersed with many water bodies such as *beels*, lakes and streams (Kushwaha and Unni, 1986). Submerged and floating plant species found in the *beels* include *Azolla pinnata*, *Cyperus* spp., *Hydrilla verticillata*, *Pistia stratiotes*, *Typha elephantine* and *Nymphaea* sps. and *Eichhornia crassipes*. The invasive water hyacinth (*E. crassipes*) covers most of the water bodies.

2.4.2 Fauna

KNP harbours rich faunal diversity, constituting of 1271 faunal species, of which 804 are vertebrates and 467 invertebrates. The 1271 faunal species are represented by six classes viz., Mammalia (n=66), Aves (n=559), Reptilia (n=75), Actinopterygii (n=80), Amphibia (n=24), and Insecta (n=467) (Appendix 1-7). *Manis pentadactyla*, *Cuon alpinus*, *Panthera tigris*, *Platanista gangetica*, *Elephas maximus*, *Bubalus arnee*, *Axis porcinus*, *Caprolagus hispidus*, *Trachypithecus geei*, *Trachypithecus phayrei*, *Hoolock prairie*, *Nycticebus bengalensis* and *Manis crassicaudata* are some of the important mammalian species reported from KNP. Kaziranga exhibits considerable diversity of avifauna because of its location at the junction of the Australasian and Indo-Asian flyways, and is recognized by Birdlife International as an "Important Bird Area". *Gyps bengalensis*, *Gyps indicus*, *Gyps tenuirostris*, *Sarcogyps calvus*, *Aythya baeri*, *Vanellus gregarius*, *Houbaropsis bengalensis*, *Emberiza aureola*, and *Ardea insignis* are the important birds reported from the area. The crocodilian *Gavialis gangeticus*, and the Testudines *Pangshura sylhetensis*, *Manouria emys* and *Nilssonia nigricans* are among the reptilians reported from the area. The fishes *Channa orientalis* and *Wallago attu*, amphibian *Ingerana borealis*, and insects *Arhopala bazaloides*, *Artipe eryx* and *Lampides boeticus* have been documented in the area.

2.5 Threats

Habitat fragmentation, poaching, flood, accident, zoonotic disease, dog attacks, burning and overgrazing are some of the major threats to the wild herbivore population in Kaziranga (Appendix 8). Habitat fragmentation due to increased anthropogenic pressures and developmental activities from the national highway (NH-37), and expansion of settlements along NH-37, agricultural areas and tea gardens make wild animals like the rhino, Asian elephant, Asiatic wild buffalo, swamp deer, hog deer, wild boar and barking deer more prone to poaching, vehicle collisions and drowning (during high floods) (Bonal, 1998; Yadava, 2014; Areendran et al., 2020). Poaching of the rhino, Asiatic wild buffalo and swamp deer for their horns and antlers for medicinal purposes also threatens their population (Patar, 2005). During high flood levels, wild animals migrate to Karbi areas, making them more prone to poaching, accident and drowning (Bonal, 1998; Yadava, 2014). Sometimes late burning of grasslands affects the fawns and calves of ungulates, and herpetofauna (Bonal, 1998; Ahmed et al., 2005). Protected Areas are increasingly facing the challenges of livestock grazing and increasing incidents of feral dog-wildlife interactions, which increases the probability of transmission of zoonotic diseases. Livestock grazing increases the chances of transmission of diseases like rinderpest and anthrax, which have reportedly impacted the populations of the Asian elephant, Asiatic wild buffalo, swamp deer and hog deer in Kaziranga (Choudhury, 1994; Bonal, 1998). Additionally, livestock competes with wild ungulates for forage, pushing the wild ungulates to inferior habitats. Grazing by livestock also alters the vegetation structure, with a preponderance of invasive plant species. Feral, stray or domestic dogs deplete the prey base for carnivores. The expansion of human settlements around KTR has increased the population of livestock and dogs around the reserve. The tall grasslands of KTR in particular are under high pressure from livestock grazing compared to other habitats (Devi et al., 2022b). Among livestock, cows exert more grazing pressure on the KTR, which is exacerbated by dogs often attacking wild animals. Activities like regular monitoring, regulating livestock grazing, formulating livelihood programmes for villagers to reduce livestock dependency, and improving veterinary assistance and dog sterilization programmes to manage their population can be implemented to overcome these issues. However, more scientific evidence is needed to understand the impact of biological invasion on the grasslands' habitat dynamic, wild animal population, disease transmission and competition.

2.6 Floods and Fire in Kaziranga

2.6.1 Floods

Frequent floods and the consequent poaching, erosion, weeds and siltation of waterbodies threaten the wildlife in Kaziranga. Floods are an annual phenomenon in KNP. The floodwater of the Brahmaputra River inundates approximately three-quarters or more area of the Park (Sarma, 2005). In KNP, floods with both positive and negative effects are a "necessary evil". Floods are beneficial as they bring in a rich deposit of silt that is essential for the maintenance of grasslands (Geethanjali, 2017). The receding floodwaters also flush out the water hyacinth from the water bodies depending on the current of the water. Due to the long spells of inundation, the water table in KNP is high throughout the year. Floods are a bane due to the heavy toll they take with respect to animal mortality. In the past decade, flood level fluctuations and intensity have been a cause of great concern to Park management. The deforestation in the upper catchment areas of the Brahmaputra River has resulted in fluctuations in the intensity of the floods. Extensive flood forces the animals and grassland-dependent species to seek refuge in higher areas where they become vulnerable to poaching and road accidents. The management strategy adopted by KNP authorities includes the formation of highlands where animals can seek shelter during the high flood. There might be a requirement for more such highlands covering a large area to protect animals during the flood season. These highlands needs to be monitored regularly to study their impact on animals.

2.6.2 Fire

Controlled burning of grasslands is a well-established practice in KNP. Almost the entire area dominated by grasslands within KNP is burnt in the post-flood season between January and February, which may extend to April, depending on the moisture regimes and grass phenology. Burning helps in the maintenance of grasslands by controlling the grassland successional processes, from short grassland communities (dominated *Imperata cylindrica*) to tall grassland communities (dominated *Saccharum* spp.). It also increases the productivity and availability of qualitative forage and enhances visibility, which facilitates anti-poaching surveillance. During control burning, grasslands are burned in patches to ensure the prolonged availability of forage, and as the low-lying and moist pockets of tall grasses are immune to fire, primarily the dry grasses are burned. Patch burning prevents the overgrazing of short grasslands by limiting the over-concentration of herbivores in this habitat type. Vegetation regrowth is phenomenally fast in the prevailing conditions and the mosaic pattern of new growth interspersed with tall grass for cover is beneficial for ungulates, as evidenced by the high ungulate density and diversity in such areas.

CHAPTER 3
SPECIES PROFILE

3.1 Introduction

Ungulata, the typical herbivore group, is a well-known traditional mammal group characterized by the presence of a hoof, modified claws, or nails surrounding the terminal toe bones or phalanges. The hoofed members of the group Ungulata are represented by two orders viz., Artiodactyla, the even-toed mammals, and Perissodactyla, the odd-toed mammals. The members without hooves are placed under Paenungulates and represented by the order Proboscidea (elephants), Sirenia (manatees and dugongs), and Hyracoidea (hyraxes) (Menon, 2014). The wide diversity of herbivores is found in Africa, Asia, Europe, and South and North America. Africa, with 94 ungulate species, represents the highest species richness among all continents (Wilson & Reeder, 2005; Ahrestani et al., 2016). Of the 83 ungulate species and 19 terrestrial mammalian herbivore species with a body size of more than 100 kg in South Asia and Southeast Asia (Ahrestani, 2009; Ahrestani et al., 2016), India harbours 39 ungulates (Prater, 1985; Wilson & Reeder, 2005) and 14 mammalian herbivores (Ahrestani, 2009). Assam in northeast India, with one of the world's highest precipitation zones and vegetation types ranging from tropical rainforest in the foothills to alpine meadows and cold deserts in the higher altitudes, supports rich biodiversity, including diverse ungulate fauna (Chandra et al., 2021).

Kaziranga National Park (KNP) supports a unique assemblage of 10 wild ungulate species, of which nine are terrestrial and one is aquatic. These 10 ungulates are represented by the order Perissodactyla viz., Greater one-horned rhino (*R. unicornis*), Proboscidea viz., Asian elephant (*E. maximus*), and Artiodactyla (also referred to as Cetartiodactyla) viz., Asiatic wild buffalo (*B. arnee*), Eastern swamp deer (*R. duvaucelii*), hog deer (*A. porcinus*), sambar (*R. unicolor*), barking deer (*Muntiacus muntjak*), wild boar (*Sus scrofa*), gaur (*Bos gaurus*) and Gangetic river dolphin (*P. gangetica*). Due to ease of accessibility to faecal samples, the present study focused on six of these 10 large herbivores species viz., Greater one-horned rhino (rhino or

GOHR), Asian elephant (elephant or AE), Asiatic wild buffalo (buffalo or WB), Eastern swamp deer (SD), hog deer (HD) and sambar (Sam) (Plate 2). Based on body size, rhinos, elephants and buffaloes with a body size of more than 500 kg are classified as mega-herbivores, while swamp deer, hog deer and sambar with a body mass of less than 500 kg are classified as meso-herbivores (Laurie, 1982; Owen-Smith, 1988; Nowak, 1999; Hutchins et al., 2004).

3.2 Order: Perissodactyla

Order Perissodactyla represents the group of odd-toed ungulates. Globally, the order Perissodactyla is represented by 17 species in six genera belonging to three families, namely Equidae, Tapiridae and Rhinocerotidae. In India, it is represented by four species and three genera (Nameer, 2000; Wilson & Reeder, 2005; Wilson & Mittermeier, 2011; Johnsingh & Nameer, 2015), including the rhino, which belongs to the family Rhinocerotidae.

3.2.1 Family: Rhinocerotidae

Globally, the family Rhinocerotidae is represented by five species, two African (*Ceratotherium simum* and *Diceros bicornis*) and three Asian (*R. unicornis*, *R. sondaicus* and *Dicerorhinus sumatrensis*) species. Of three Asian rhino species, two species, namely *R. unicornis* and Javan rhinoceros (*R. sondaicus*), were reported from India earlier; however, presently, only one rhino species (*R. unicornis)* occurs in India with the Javan rhinoceros is restricted only to Myanmar (Johnsingh & Nameer, 2015).

3.2.1.1 Greater one-horned rhino (*Rhinoceros unicornis)*

3.2.1.1a General Description

The Greater one-horned rhino is the second-largest living rhino and the fourth-largest terrestrial mammal (Dinerstein, 2015). Adult male rhinos are larger than adult females, with sizes varying between 365 and 385 cm, and shoulder height between 165 and 186 cm. In adult females, the size varies between 300 and 350 cm, and shoulder height between 145 and 175 cm. Males are heavier, with average weight ranging from 2000 to 3000 kg, while the weight of adult females weight ranges between 1500 and 2200 kg. The presence of a single large bulky horn of about 20 to 30 cm is typical for both male and female rhinos. The tail length varies between 70 and 105 cm. The skin color of rhinos is deep slate grey, which might look ashy or ink black when they spend more time in muddy water. The skin is almost without hair and has tubercles (loose folds and lumps) that give the armor-plated appearance (Menon, 2014). Generally, males have thicker neck folds, marginally long horns, and large sharp incisors. The presence of a semi-prehensile upper lip helps in foraging activities. Rhino is a solitary animal and prefers tall alluvial grasslands, a mosaic of riverine forest grasslands, and swampy areas (Menon, 2014). They are excellent swimmers and can run at a speed ranging between 40 and 55 km/hr for a short period. They spend most of their time foraging, and primarily act as grazers throughout the year, feeding mainly on *Saccharum spontaneum*, whereas in winter, they act as browsers (Gyawali, 1986; Dinerstein, 2015). When not engaged in foraging, they require water bodies to immerse themselves in.

3.2.1.1b Population status

Rhino, once present throughout the Indo-Gangetic and Brahmaputra floodplains covering Pakistan, India, Nepal, Bangladesh, Bhutan and Myanmar, is now restricted to northeastern India and Nepal (Laurie, 1978; Dinerstein, 2003). During the first decade of the 20th century, rhinos were on the edge of extinction in India with only a dozen individuals (Gee, 1952). In the second half of the 20th century, rhinos were reported only from Assam, Bengal and Bihar in India, and speculated as wanderers from Nepal (Gee, 1952). Presently, in India, rhinos are restricted to the Protected Areas of Assam, Uttar Pradesh, and West Bengal. Assam holds the world's largest population of the Greater one-horned rhinos in KTR; a significant population also resides in other Protected Areas viz., Manas National Park, Orang National Park, Laokhowa Wildlife Sanctuary, Dudhwa National Park, Katarniaghat Wildlife Sanctuary, Jaldapara National Park and Gorumara National Park (Foose & Strien, 1997). The rhino population in KNP has increased from a dozen in 1912 to 2613 in 2022 (Patar, 2005; Yadava, 2014; Assam Forest Department).

3.2.1.1c Conservation status

Rhino was listed as Endangered in the IUCN Rare Endangered and Threatened (RET) list until 1996, and later upgraded to Vulnerable primarily due to an increase in their population. Rhino is protected under Schedule I of the Indian Wild Life (Protection)

Act, 1972 (IWPA) and is placed in Appendix I of CITES (Convention on International Trade in Endangered Species). Hunting as a sport during the late 1800s and early 1900s reduced the population of rhinos. The anthropogenic pressures and constructional activities from the 1900s onwards reduced the habitat availability and increased the reduction in their population (Laurie, 1978; Dinerstein & Price, 1991; Bhattacharya, 1994). In India, the pioneering step towards rhino conservation happened in the early 1900s when the rhino-occupied area of Kaziranga was declared a Game Reserve and later upgraded to a Wildlife Sanctuary, National Park and Tiger Reserve.

Habitat fragmentation and degradation, encroachment, poaching driven by the immense value of rhino horn in traditional medicine have reduced their population (IUCN, 2022). The high population of rhinos in KNP provides translocation opportunities to nearby Protected Areas (Yadava, 2014). The Government of Assam launched the Indian Rhino Vision 2020 programme in 2005 with an aim to increase the population of rhinos to 3000 rhinos by 2020. As a part of this programme, rhinos were translocated from the highly populated KNP to Manas National Park. The programme was successful as it curbed poaching and improved rhino conservation efforts in Assam, and unsuccessful as it didn’t achieve the goal of 3000 rhinos by 2020. The increased security in Protected Areas, armed guards, involvement of the national army and intelligence network against poaching reduced poaching pressure on rhinos.

3.3 Order: Proboscidea

The old-world mammals belong to the order Proboscidea. Globally, three species belonging to two genera and one family, the Elephantidae, represent the order Proboscidea. In India, the order Proboscidea is represented by only one species, the Asian elephant (Johnsingh & Nameer, 2015).

3.3.1 Family: Elephantidae

Family Elephantidae is represented by two genera viz., *Elephas* (Asian) and *Loxodonta* (African), and three species, namely *E. maximus*, *L. africana* and *L. cyclotis* (Johnnsingh & Nameer, 2015).

3.3.1.1 Asian elephant (*Elephas maximus*)

The Asian elephant is represented by four living subspecies viz., Sri Lankan Asian elephant (*E. m. maximus*), Indian elephant (*E. m. indicus*), Sumatran Asian elephant (*E. m. sumatranus*) and Borneo Pygmy elephant (*E. m. borneensis*) (Fernando et al., 2003; Santiapillai & Sukumar, 2006). The present study focused on *E. m. indicus*, which occurs in the Asian mainland.

3.3.1.1a General Description

This charismatic flagship species and the largest terrestrial mammal still exist in the wild (Menon, 2014). The average height of an elephant is up to 6.4 m, and the shoulder height is 3 m. Elephants are heavy with an average weight of approximately 5 tons. The skin is wrinkled and grey in color. The presence of large trunks and sail-like ears are the typical characteristic features for their identification. Elephants show sexual dimorphism and are polygynous (Sukumar, 2003). The presence of a large tusk is a peculiar feature of the male elephant. On the other hand, females have tushes, a small dental protuberance. Some males without tusks are called *makhnas* and are differentiated from females by the penis bilge below the tail (Menon, 2014). Elephants are generalists by virtue of their large and grinding molars, which allow them to feed on different plant parts, including stem, bark, fruit, pith, grass, and whole plant, and use diverse habitats viz., mixed forest, scrubland, floodplain and grasslands (Menon, 2014; Johnsingh et al., 2015). They spend most of their time foraging to fulfill their body needs and can consume up to 240 kg of forage species within 18 hours of foraging time (Sukumar, 1989; Desai, 2001; Johnsingh et al., 2015). They defecate about 100 kg of dung within a day. Females are sociable and form a herd of related females, which is led by the oldest female *matriarch*. Elephants are the first mammal known to communicate via very low-frequency infrasonic calls that cannot be heard by the human ear (Payne et al., 1986).

3.3.1.1b Population status

In the beginning of the 20^{th} century, more than one lakh elephants existed in the wild, which reduced by ~50% over the years, and is still declining globally (IUCN, 2022). Elephants occur in the South Asian countries of Bangladesh, Bhutan, India, Nepal and Sri Lanka, and Southeast Asian countries of Cambodia, China, Indonesia, Lao People’s

Democratic Republic (PDR), Malaysia, Myanmar, Thailand and Vietnam. They are extinct from West Asia, Java and most of China. In India, once widespread, elephants are now restricted to northeastern India, central India, northwestern India and southern India. The isolated and fragmented population of elephants faces threats in all its distribution ranges. The total population of elephants in the wild was estimated to range between 36,000 and 52,000 (Santiapipillai & Sukumar, 2006). In KNP, the population of elephants number had increased from 349 in 1966 to 1163 in 2011 (Spillett, 1966; Pathak, 1978; Patar, 2005; Yadava, 2014).

3.3.1.1c Conservation status

The Asian elephant is listed as Endangered in the IUCN RET list, protected in Schedule I of the IWPA, and is placed in Appendix I of CITES. Prominent threats to the elephant include habitat loss, degradation and fragmentation, and increasing human-elephant conflict exacerbated by the exponentially growing human population (Sukumar, 2003). In India, elephants are threatened by human-elephant conflict and the poaching of male elephants for tusks (illegal ivory trade). India used to lose well over a hundred elephants a year to poaching for tusks (Menon, 2014). The IUCN/Species Survival Commission Asian Elephant Specialist Group is the coordinating body for elephant conservation and produced the 1990 Action Plan that outlined the conservation measures required. These include establishing a network of Protected Areas for elephant conservation, creating corridors to facilitate elephant migration, mitigating human-elephant conflict, translocating elephants from areas where they have become pests, control of poaching, and further research to make appropriate management recommendations. Project Elephant, launched in 1992, implemented the recommended conservation measures, reduced the pressures on the elephant population, and led to the involvement of numerous leading Indian conservation organizations in elephant conservation, namely Wildlife Trust of India, Asian Nature Conservation Foundation, Ashoka Trust for Research in Ecology and the Environment, Aaranyak, Nature Conservation Foundation, World Wide Fund for Nature-India, and local Non-Governmental Organizations.

3.4 Order: Artiodactyla

Artiodactyla is a group of even-toed hoofed mammals that occur globally, except in Australia and Antarctica (Johnsingh & Nameer, 2015). Globally, the order Artiodactyla represents 240 species and 89 genera belonging to five families viz., Suidae, Tragulidae, Moschidae, Bovidae and Cervidae. In India, the order Artiodactyla represents 40 species and 25 genera belonging to five families. Of the five Artiodactyla families, the present study focused on one Bovidae species and three Cervidae species.

3.4.1 Family: Bovidae

Globally, the family Bovidae represents 143 species and 50 genera, and in India, it represents 25 species and 16 genera (Nameer, 2000; Wilson & Reeder, 2005; Wilson & Mittermeier, 2009; Johnsingh & Nameer, 2015). Four living genera come under the tribe Bovini viz., *Bubalus*, S*yncerus, Bos* and *Bison* (Gentry, 1992; Sankar et al., 2014). The present study focused on only one bovine species, the Asiatic wild buffalo (*Bubalus arnee*).

3.4.1.1 Asiatic wild buffalo (*Bubalus arnee)*

Genus *Bubalus* includes three wild species, namely Anoa (*B. depressicornis*), found only in Indonesia, Tamaraw (*B. mindrorensis*), endemic to Philippines, and Asiatic wild buffalo (*B. arnee*). IUCN considered *B. arnee* as a wild form of water buffalo and *B. bubalis* as a domestic form (Gentry *et al*. 2004). Groves (1996) identified three subspecies of *B. arnee* that are all still extant viz., *B. a. arnee* (India and Nepal), *B. a. fulvus* (Assam and neighboring areas) and *B. a. theerapati* (Southeast Asia). Differentiating Asiatic wild buffalo from feral, domestic and hybrid stock is challenging, making population surveys difficult. Some scientists suggest that there might be no genetically pure wild buffalo since interbreeding with domestic buffalo is widespread.

3.4.1.1a General Description

The Asiatic wild buffalo is a blacker, sleeker and heavier version of the domestic buffalo and is considered as one of the most dangerous animals to encounter in India. It can be differentiated from domestic and hybrid buffaloes by using characteristic features like a straight back, larger and more spread-out horns, pinkish instead of white hair on the inside of the ears, and large hooves leaving big telltale footprints. Asiatic wild buffalo are massive and barrel-chested, with short legs. Males are larger than females. The shoulder height ranges between 1.3 to 1.8 m, and the average weight ranges from 600 to 900 kg. It possesses massive horns measuring over 1m (average) in length. Parietals form a wide zone on the top of the cranium and are separated from the frontals. The horns emerge from the head towards the posterior, and tend to be triangular in cross-section. These are crescent-shaped and smaller in males (130-140 cm) and longer in females (130-150 cm); however, the girth and span of the horns is smaller in females. The hair on the back of the body goes forward from the rump to the nape; the ears are small, droop downwards, and are not fringe (Mishra, 2001).

The skin has few sweat glands and relatively fewer hair. The lower legs are pale, but this can be difficult to distinguish since buffaloes frequently wallow in the mud. It has wide hooves with joints that are very flexible for walking in mud. It has short legs and cannot run fast. Both male and female buffaloes are slate-gray to black in color. In adults, the color of the male is darker than the females, while the young ones are almost brown. The buffaloes are mainly found in herds, except for the solitary bull. Asiatic wild buffaloes occur principally in low-lying alluvial grasslands, riparian forests and woodlands (Prater, 1971; Choudhury, 1994). Buffalo attains maturity at 18 months. Its life span is about 25 years in the wild and 29 years in domestic conditions. The gestation period lasts 300 to 340 days, and they give birth to a single calf per birth, usually at an interval of two years. Weaning occurs after 6-9 months. Wild buffalo prefer to forage in the morning and evening and rest and wallow during the midday in dense cover and wetlands, respectively. The paucity of studies on the ecology of wild buffalo makes it challenging to predict their feeding habits (Ahrestani et al., 2016).

3.4.1.1b Population Status

Wild buffalo are currently restricted to India, Nepal, Bhutan, Thailand, Cambodia and Myanmar, and are extirpated from Bangladesh, Indonesia, Vietnam and Lao PDR (IUCN, 2022). Globally, less than 4000 individuals of wild buffalo occur in the wild, which includes less than 2500 mature individuals (IUCN, 2022). In India, buffalo, once widespread in the Ganga, Brahmaputra and Godavari floodplains, is now restricted to the Protected Areas in the Ganga and Brahmaputra River Basins (Mishra & Gaur, 2019). Almost half of the buffalo population is extirpated from its range, mainly due to hybridization. In northeast India, Choudhury (1994) reported about 3300 to 3500 wild buffalo individuals, mostly from Assam, followed by Arunachal Pradesh and Meghalaya. Choudhury (2010) reported about 2800 to 3000 buffalo individuals from northeast India (IUCN, 2022). The main populations of wild buffalo are found in the Protected Areas of Kaziranga National Park (N=2600), Dibru-Saikhowa National Park (N=400), and Manas National Park (N=250) in Assam (IUCN, 2022). In Meghalaya, about 50 individuals of buffalo have been reported (Choudhury, 2010; IUCN, 2022). In Arunachal Pradesh, the species used to occur in and around East Siang and Dibang valley; however, there is lack of recent records of their occurrence in the area (Choudhury, 1994: IUCN, 2022). In 1988, around 100 wild buffalo individuals were reported in the wild from central India (IUCN, 2022). Over a span of four decades, the wild buffalo population in KNP has increased from 471 in 1966 to 1937 in 2008 (Spillett, 1966; Pathak, 1978; Patar, 2005; Yadava, 2014).

3.4.1.1c Conservation Status

Asiatic wild buffalo is listed as Endangered in the IUCN RET category, protected in Schedule I of the IWPA, and placed in Appendix III of the CITES. In India, the population of wild buffalo is restricted to the Protected Areas of Assam (Kaziranga National Park, Dibru Saikhowa National Park & Manas National Park), Arunachal Pradesh (D'Ering Memorial Wildlife Sanctuary), Meghalaya (Balpakram National Park), and Chattisgarh (Indravati National Park and Udanti Wildlife Sanctuary). Habitat loss, agricultural expansion, poaching, hunting, hybridization, zoonotic diseases and competition are the principal reasons behind the declining wild buffalo (Choudhury, 1994). Choudhury (1994) reported that during the flood season, the Asiatic wild buffalo was hunted for food by the Mising tribe of Lakhimpur and Dhemaji districts in Assam, and the Adi tribe of East Siang and Dibang Valley districts in Arunachal Pradesh. Hybridization of the Asiatic wild buffalo with domestic and feral buffaloes also threatens the wild buffalo population in South Asia and Southeast Asia (Choudhury, 1994; Muley, 2001). Rinderpest and other zoonotic disease spread via domestic buffaloes have the potential to extirpate the population of Asiatic wild buffalo. In 1981, around 150 buffalo casualties were documented from KNP due to Rinderpest (Choudhury, 1994). The management of the wild population of Asiatic wild buffalo requires active adaptive management, which should also consider domestic buffaloes.

3.4.2 Family: Cervidae

The ruminant ungulates belong to the family Cervidae, the deer family. Antlers, the branched appendages, are the typical feature of male deer belonging to the family Cervidae (Menon, 2014). The members of the family Cervidae do not have gall bladder and incisors in the upper jaw, though they sometimes show the presence of canines (Menon, 2014). Globally, the family Cervidae represents 51 species belonging to 19 genera; in India, it represents eight species belonging to five genera (Nameer, 2000; Wilson & Reeder, 2005; Wilson & Mittermeier, 2009; Johnsingh & Nameer, 2015). Of the eight deers, the present study focused on three deer species viz., the eastern swamp deer (*R. duvaucelii*), hog deer (*A. porcinus*), and sambar (*R. unicolor*).

3.4.2.1 Eastern swamp deer (*Rucervus duvaucelii*)

Three species within the genus *Rucervus* are recognized globally, namely Indian swamp deer (*R. duvaucelii*), brow-antlered deer (*R. eldii*), and extinct Schomburgk's deer (*R. shomburgki*) (Martin & Gopal, 2015). Globally, three subspecies of swamp deer are recognized, and all have their distribution range in India. The soft-ground barasingha (*R.d. duvaucelii*) occurs in the Himalayan foothills, hard-ground barasingha (*R.d. branderi*) occurs only in central India, and eastern barasingha (*R. d. ranjitsinhii*) occurs only in the Protected Areas of Assam, namely Kaziranga National Park and Manas National Park (Martin & Gopal, 2015).

3.4.2.1a General Description

The swamp deer is a large deer that occurs only in the Indian subcontinent. The height of mature males varies from 115 to 125 cm, and from 100 to 110 cm in mature females. Males are generally heavier than females, with an average weight ranging from 170 to 180 kg (Martin & Gopal, 2015). Their coat color varies from bright orange to dark brown, with white rump, inner leg, and underside of the tail. Generally, males are slightly darker than females. In summer, the color of the coat becomes bright rufous-brown with white spots along the spine. In winter and autumn, the color of the pelage becomes greyish-brown and gets shaggy during moult. They have a typical antler pattern with 5-6 tines on each side that count up to twelve, and commonly referred to as *barasingha*, meaning "twelve pointer". These antlers are generally large and grow up to 1m in length. Swamp deer have long and broad hooves. It prefers alluvial grasslands, tall floodplains grasslands, swampy areas, and dry to moist deciduous forests (Menon, 2014; Martin & Gopal, 2015). In KTR, swamp deer prefer both short and tall grassland areas; foraging on short grasses and using tall grasslands for shelter (Talukdar, 1999; Banerjee, 2001). They act as mixed feeders, and are involved in both grazing and browsing (Martin & Gopal, 2015; Ahrestani et al., 2016). Eastern swamp deer is overshadowed by charismatic species such as rhino (*R. unicornis*), tiger (*P. tigris*), and elephant (*E. maximus*), and remain neglected, and thus little is known about their conservation science.

3.4.2.1b Population status

The swamp deer once occurred west of the Indus River in Pakistan and as far south as the Godavari River in east-central India (Schaller, 1967; Sankaran, 1989). Presently it is restricted to India and Nepal, and extirpated from Bangladesh and Pakistan (IUCN, 2022). In India, swamp deer occur in small patches in the Ganga and Brahmaputra floodplains in north, northeast and central India. It's present distribution in India is limited and fragmented, primarily due to habitat fragmentation & degradation, and hunting (IUCN, 2022). Once distributed throughout the Brahmaputra floodplains and the terai foothills of the Eastern Himalayas, the eastern swamp deer is now restricted only to the Protected Areas in Assam. With less than a thousand individuals, the population of eastern swamp deer is facing a threat of extinction. The population of eastern swamp deer (*R. d. ranjitsinhi*) increased from 200-250 in 1965, to 520 in 1972, ~700 in 1978, and ~750 in 1984, and declined to 350-500 individuals by 1994 (Schaller, 1967; Lahan & Sonowal, 1973; Kusvaha et al., 1986; Choudhury, 1987; Qureshi et al., 1995). In more than five decades, the population of swamp deer in KNP has increased from 213 in 1966 to 868 in 2022 (Spillett, 1966; Pathak, 1978; Bonal, 1998; Patar, 2005; Yadava, 2014; Assam Forest Department).

3.4.2.1c Conservation status

Swamp deer is listed as Vulnerable in the IUCN RET category, protected under Schedule I of the IWPA, and placed in Appendix I of the CITES. The Protected Areas in Assam, namely Kaziranga National Park and Manas National Park, are a cornerstone in protecting the eastern swamp deer population. The species is under severe threat due to increasing anthropogenic pressure on floodplain grasslands (IUCN, 2022). In

Kaziranga, the species is under pressure due to habitat fragmentation, overgrazing by livestock, poaching, zoonotic disease, invasion of exotic plant species, floods and changes in river dynamics due to climate change and increasing anthropogenic pressures (Bonal, 1998; Patar, 2005; Ahmed et al., 2005; Yadava, 2014; Sharma & Sarma, 2014). Increasing siltation rate, and reduction in water flow, mostly during summers, threaten the swamp deer population. Seasonal migration during high floods makes eastern swamp deer more prone to accidents, and poaching and hunting for antlers and meat; thus, migrating population, outside Protected Areas, also requires protection. The threats to swamp deer can be overcome by limiting habitat degradation, poaching, developing long-term conservation and habitat management plans, and reducing livestock grazing pressures (Qureshi et al., 1995). The Protected Area management plans are important to ensure the conservation of swamp deer within the ecosystem.

3.4.2.2 Hog deer (*Axis porcinus*)

In the Asian continent, the genus *Axis* is represented by four species viz., *A. porcinus*, *A. axis*, *A. calamianensis* and *A. kuhlii* (Dhungel et al., 1991; Moore, 2015). Ellerman and Morrison Scott (1951) classified the hog deer into two subspecies, the Indian hog deer (*A. p. porcinus*) and the Indochinese hog deer (*A. p. annamiticus*). The Indian hog deer occurs in India, Nepal, Pakistan, Myanmar and Sri Lanka (Moore, 2015), and the Indochinese hog deer in India, Thailand and Indo-China (Dhungel et al., 1991; Gupta et al., 2018).

3.4.2.2a General Description

Hog deer is among the well-studied medium-sized deer (Moore, 2015). The stags (male) are larger in size, with a shoulder height of ~70 cm high, and the hinds (female) are smaller, with a shoulder height of ~61 cm. The stags are heavier and weigh ~50 kg, whereas the lighter hinds weigh around 30 kg. The color of the coat is light brown to a rich, reddish brown in summer, and speckled dark brown in winter. Antlers are a typical feature of males and are absent in females. Each side of the antlers has three tines; the brow tine with a solid main beam forms the acute angle, terminating in the inner and outer top tines. Hog deers are mostly crepuscular and active during the mornings and late afternoons (Dhungel et al., 1991). The studies conducted in India showed that hog deer utilize tall, moist, alluvial terai grasslands in the Gangetic and Brahmaputra floodplains (Moore, 2015; Biswas, 2004). They primarily act as grazers and graze on herbs, forbs and short grasses, and browse on palatable shrub species (Moore, 2015). Miller (1975) conducted a study on the diet composition of hog deer and revealed that their diet primarily constituted of 80% grasses, and 20% forbs and browse. Hog deer, in their areas of occurrence, form an important prey base for large predators (Dinerstein, 1979; Dhungel et al., 1991; Moore, 2015).

3.4.2.2b Population status

Hog deer once occurred in Pakistan, northern and northeast India, Nepal, Bhutan, Bangladesh, Myanmar, Cambodia, Thailand, Vietnam and Lao PDR (Dhungel et al., 1991; Biswas, 2004; IUCN, 2022). Presently, they occur in Pakistan, Bangladesh, India, Nepal, Bhutan, Myanmar and Cambodia (IUCN, 2022). Tandon (1989), Johnsingh et al. (2004), and Biswas (2004) found that in India, hog deer are found mainly in terai grasslands along the Himalayan foothills and the Gangetic and Brahmaputra floodplains, from Punjab in the west to Arunachal Pradesh in the east. Its range and numbers have fallen because of overhunting and habitat loss. Their habitat of preference is often suitable for human cultivation and settlement. Thus, with an increase in human population, the habitat availability for hog deer decreased, resulting in the disappearance of hog deer from many places. In Southeast Asia, more than 90% of the hog deer population declined between 1991 and 2012. Most hog deer populations are now highly scattered and are presently restricted to Protected Areas only. KNP supports a significant population of hog deer, and is one of the strongholds in India. In four to five decades, the population of hog deer in KNP has increased from 1311 in 1966 to 3500 in 2012 (Spillett, 1966; Pathak, 1978; Patar, 2005; Yadava, 2014).

3.4.2.2c Conservation status

Hog deer are listed as Endangered in the IUCN RET category, protected in Schedule I of the IWPA, and placed in Appendix III of the CITES. Major threats to hog deer include hunting (primarily for bush meat), habitat loss due to human settlements and agriculture, and the subsequent fragmentation of populations. Hog deer shares its range with the Greater one-horned rhino, Asian elephant, brow-antlered deer, gaur, chital, swamp deer, sambar, and barking deer; thus, conservation measures taken for these species also benefit hog deer (Moore, 2015). Most of the hog deer range is presently confined to Protected Areas (Biswas et al., 2002). Johnsingh et al. (2004) found a strong correlation between hog deer subpopulations and Protected Areas in the terai arc landscape of India (similar to the *R. duvaucelii*). Wildlife protection laws in India and Protected Areas have played a crucial role in conserving the species in their range. Some Protected Areas are not big enough to allow adequate ranging during heavy flood periods, leading to heavy mortality during such periods. Since new grasslands are rarely formed by natural processes, the present grasslands are too small to be allowed unfettered habitat succession. Being a floodplain species, the hog deer are affected by the reduction in the extent and the quality of floodplain grasslands and poaching, although the largest population of the species in KNP is secured from this threat. In recent years, decrease in the extent of quality wetland habitat in the park and increased invasion of *Mikania micrantha* poses a potential threat to its continuous existence. While hog deer are still present in substantial numbers in some parks throughout India and Nepal, threats to their existence continue due to human activities directly affecting parks or indirectly affecting park boundaries.

3.4.2.3 Sambar (*Rusa unicolor*)

Grubb (1990) placed the sambar deer in the genus *Rusa*, as *R. unicolor*, which was earlier placed in the genus *Cervus*. Seven subspecies of the sambar deer are known, of which only one is found in India, *R.u. unicolor* (Khan & Johnsingh, 2015). The other six subspecies of sambar include *R. u. hainana, R. u. dejeani, R. u. cambojensis, R. u. equina, R. u. brookei,* and *R. u. swinhoii*.

3.4.2.3a General Description

In South East Asia, the sambar represents one of the largest deer, about 100 to 150 cm high at the shoulder. The average weight of adult males and females varies between 225 and 320 kg, and 135 and 225 kg, respectively (Khan & Johnsingh, 2015). The color of the coat is grey-brown to dark brown in winter, and brown to chestnut brown in summer. Males are darker than females. The tail is generally 15 to 30 cm in length, and black in colour with a rusty brown underside. Antlers are a typical feature of male sambars, which may vary in length from 90 to 129.2 cm in adult males. The antlers have three tines on either side, and shed annually. Sambar prefers forest, marsh and woodland habitats, including moist evergreen forests, tropical dry forests, subtropical mixed forests and tropical rain forests and avoids areas with high anthropogenic pressures (Varman & Sukumar, 1993; Sankar, 1994; Harikumar et al., 1999; Jayson, 1999; Khan & Johnsingh, 2015). The use of a variety of habitats enhances the ease of accessibility to a wider variety of plants for forage (Schaller, 1967; Khan & Johnsingh, 2015). Browsing and grazing by sambar depend upon forage availability during different seasons. They tend to browse more during the summer and winter seasons, and graze more in the wet season (Schaller, 1967; Martin, 1977; Bentley, 1978; Dinerstein, 1979; Kelton et al., 1987; Ngampongsai, 1987; Sankar, 1994; Khan & Johnsingh, 2015). Sambar exhibit nocturnal behaviour, as they are more active during the night (Shea et al., 1990).

3.4.2.3b Population status

Sambar is the most widespread deer, and its distribution extends from Philippine Islands in the east, through Indonesia, southern China, Indo-china, Thailand and Myanmar, to India in the west (Varman & Sukumar, 1993; Khan & Johnsingh, 2015; IUCN, 2022). Despite the wide distribution range in southern Asia and flexibility in habitat utilization, sambar is currently restricted to Protected Areas (Sankar & Acharya, 2004; Leslie, 2011). Due to its predominantly crepuscular to nocturnal behaviour, small group size and general shyness, conducting a sambar census is challenging (Schaller, 1967; Eisenburg & Lockhart, 1972; Leslie, 2011). Sambar occurs in 208 Protected Areas in India and is one of the most commonly sighted Cervid species, especially in the three south Indian states of Karnataka, Tamil Nadu and Kerala (Sankar & Acharya, 2004, IUCN, 2022). In central and east Indian states, sambar is very rare, with an extremely patchy distribution and severely declined population, due to heavy hunting pressures, insurgency and rapidly spreading mines (both bauxite and iron-ore). In India, the sambar population exceeds 50,000 (Nowak, 1999). The reported ecological densities of sambar in India mostly range from 1–10 individuals per km^2 within the Protected Areas Network. In more than four decades, the population of sambar in KNP has increased from 120 in 1966 to 1100 in 2012 (Spillett, 1966; Pathak, 1978; Yadava, 2014).

3.4.2.3c Conservation status

Sambar is listed as Vulnerable in the IUCN RET list and protected in Schedule III of IWPA. It is the only large Indian ungulate that has adapted itself to a wider variety of forest types and environmental conditions (Schaller, 1967). In India, the species is restricted to Protected Areas, with rampant poaching affecting its population in these areas. Habitat encroachment and hunting for sport, meat, medicinal products and other purposes are major threats to their population (Jathanna et al., 2003; Kumara & Singh, 2004). In India, the relocation of forest-dwelling communities residing around Protected Areas (Bhadra and Kudremukh in Karnataka) has resulted in an expansion of habitat available to sambar, and reduction in hunting and grazing competition from livestock (Karanth et al., 2006). In Protected Areas, the presence of forest staff and their dispersion across the area is effective in the conservation of large mammals (Lynam et al., 2006). Habitat fragmentation and degradation, floods, accident and overgrazing by livestock are the major causes of concern to their population in KNP (Yadava, 2014).

CHAPTER 4
DIET COMPOSITION OF SIX SYMPATRIC LARGE HERBIVORE SPECIES

Summary

In the dry savanna of Africa, it has already been established that small-bodied meso-herbivores tend to browse more, while mega-herbivores are involved more in grazing and mixed feeding. Despite having a variety of large herbivore species, India has contributed very little to the science of community ecology, which hinders the development of science-based conservation measures. The present study was aimed at addressing this gap by assessing the feeding habits of three mega-herbivores viz., greater one-horned rhino, Asian elephant and Asiatic wild buffalo, and three meso-herbivores viz., swamp deer, hog deer and sambar. The study was conducted in the riverine alluvial grasslands of the Kaziranga National Park (KNP), where seasonal floods and fire play an important role in shaping the vegetation structure. The diet composition was assessed using the micro-histological technique. A bipartite ecological network was used to visualize the diet composition of mega- and meso-herbivores.

Results revealed that both mega- and meso-herbivores were grazers and mixed feeders, as they consumed more than 50% of monocots. Compared to the dry season, these herbivores consumed more monocots in the wet season. From the dry to wet season, the elephant and sambar shift their diet from browsing to grazing. Irrespective of seasons, grasses contributed most to the diet of the six large herbivores. Forage plants belonging to Poaceae and Cyperaceae families contributed more than 50% to the diet of mega- and meso-herbivores. From the dry to the wet season, the six large herbivores increased the consumption of forage plants belonging to Poaceae and Cyperaceae families. Overall, 25 forage plants constituted more than 70% of their diet. Among monocots, family Poaceae with *Saccharum* spp. (contributing >9% of the diet), and among dicots, family Rhamnaceae with *Ziziphus jujuba* (contributing > 4% of the diet) fulfilled the dietary needs of mega- and meso-herbivores.

In conclusion, both mega- and meso-herbivores consumed a more graze-based diet in the wet season than in the dry season. Possibly due to the availability of higher quality monocots in the wet season, both mega- and meso-herbivores consume them in high proportion. Compared to other herbivores, the diet of the rhino, elephant and sambar consisted more of browse. This can be attributed to forage and habitat availability, predation risk, seasonal floods, and management practices such as controlled burning of the grasslands. The ongoing succession and invasion processes, anthropogenic pressures, and lack of grassland conservation policy are expected to affect the availability of the principal forage plants and habitat of large herbivores in the Brahmaputra floodplains, which necessitates wet grassland-based management interventions for the continued co-existence of large herbivores in such habitats.

4.1 Introduction

Herbivores primarily depend on plant communities to fulfil their dietary requirement (Augustine & McNaughton, 1998). Food is one of the fundamental elements of a niche and crucial for survival (Krebs, 1999; Tewari & Rawat, 2013; Portella & Vieira, 2016). The Jarman–Bell principle emphasizes that the quality and quantity of large herbivore diet correlates with their body size (Bell, 1971; Jarman, 1974; Wegge et al., 2006). Thus, based on body size, the amount of forage requirement and time spent on foraging varies (Wegge et al., 2006; Bawri & Saikia, 2014). Mega-herbivores, with their large body sizes, feed on a large amount of forage and are less selective (Wegge et al., 2006). Meso-herbivores, with their small body sizes, feed on a small quantity of forage; therefore, they tend to be more selective (Owen-Smith, 1988; Arsenault & Owen-Smith, 2002; Wegge et al., 2006).

Based on preference for the two major plant types, monocots (grasses and sedges) and dicots (herbs, shrubs and trees), herbivores are categorized as grazers, browsers or mixed feeders (Hofmann & Stewart, 1972; Ahrestani et al., 2016). Grazers feed mainly on graminoids or monocots, browsers feed mainly on browse or dicots, and mixed feeders feed on both monocots and dicots based on forage availability. Any changes in the consumption of monocots (grazing) and dicots (browsing) result in changed diet composition.

The information on diet composition focusing on species-based diet helps to explain and understand the changes occurring in different forage category levels viz., monocots and dicots, growth forms, families and taxa. From conservation point of view, information on diet composition is an important factor that will not only aid in improving the habitat quality but also both ex-situ and in-situ conservation (Sarkar et al., 2012). Hence, understanding the diet composition is a crucial step towards understanding the chance of survival and reproductive behaviour of a species, which further helps in the management of their habitat and helps in evaluating the quality of their habitat (Portella & Vieira, 2016). Many studies on herbivore foraging ecology have already been conducted in Asia, with a focus on one to four wild ungulate species (Ahrestani, 2012; Wegge et al., 2006). Except in Europe and Africa, limited studies have examined the diet composition of more than four wild sympatric herbivores (Ahrestani, 2012; Pradhan et al., 2008).

The present study is an effort to provide the first-ever detailed diet study of six large herbivore species (SLH) from Asia. KNP provides the opportunity to understand the diet composition of specifically six sympatrically occurring large herbivore species, namely three mega-herbivores viz., greater one-horned rhino, Asian elephant and Asiatic wild buffalo, and three meso-herbivores viz., swamp deer, hog deer and sambar. Based on literature review, mega-herbivores are grouped under the coarse feeder category, as they require an abundant supply of forage to fulfil their body requirements within a limited time, which also makes them feed on poor-quality forage (Wegge et al., 2006; Pradhan et al., 2008). Meso-herbivores are grouped under the soft feeder category, as they feed on small quantities of fresh, nutritious and highly palatable forage (Putman, 1996; Ahrestani et al., 2016).

The literature review also revealed that compared to the dry season, the rhino, Asian elephant, Asiatic wild buffalo, swamp deer, hog deer and sambar graze more during the wet season, which suggests that season influences the diet composition (Wegge et al., 2006; Pradhan et al., 2008; Baskaran et al., 2010; Bawri & Saikia, 2014; Semiadi et al., 1995). The present study deals with the seasonal feeding behaviour of SLH, to identify their dietary intake at four different levels: i) browse to graze ratio in terms of monocot and dicot consumed; ii) in terms of the growth form that is further categorized into six subcategories viz., grasses, sedges, climbers, herbs, shrubs and trees; iii) in terms of families and iv) in terms of the forage species consumed. The present chapter aims to provide answers to the following research questions:

Is there any difference in the diet composition of SLH in each season in terms of:

a) monocot and dicot
b) six categories of growth form viz., grasses, sedges, herbs, shrubs, climbers and trees.
c) the forage plant species contributing to the diet.

4.2 Methodology

4.2.1 Micro-histology

Micro-histology, one of the most widely used techniques to study the food habits of herbivores, was used to study the dietary patterns of the mega- and meso-herbivores (Stewart, 1967; Todd & Hansen, 1973; Holechek et al., 1982; Shrestha et al., 2005; Wegge et al., 2006; Tewari & Rawat, 2013; Tuboi & Hussain, 2016). The technique involves the preparation of reference slides from the plant material (leaf, stems, flower, and fruit) and comparing it with the slides prepared from the known faecal samples of mega- and meso-herbivores (Sparks & Malechek, 1968; Wegge et al., 2006).

4.2.2 Sample Collection

4.2.2.1 Reference plant collection

A total of 75 potential forage species belonging to 31 families were collected. Among the collected forage species, 72% (n = 54) were dicots and 28% (n = 21) were monocots. With respect to growth form, 33 herb species (44%) were collected, followed by 13 grass species (17.33%), 13 shrub species (17.33%), six sedge species (8%), five climber species (6.66%), and five tree species (6.66%). A total of 42.66% (n = 32) of forage species were collected from short grasslands and areas near *beels*, followed by 29.33% (n = 22) from tall grasslands and 28% (n = 21) from woodland areas. The reference plant materials were collected in the field based on literature survey and direct sighting (Chetri, 2006; Tewari & Rawat, 2013). The taxonomic identification of reference plant materials was based on the flora of the KNP (Jain & Hajra, 1975; Hajra & Jain, 1994). After collection, the material was oven-dried at 60 °C for 48 hours, stored in labelled paper bags, and later brought to the Wildlife Institute of India for further laboratory analysis (Vila et al., 2009).

4.2.2.2 Faecal sample collection

Fresh dung samples of the mega-herbivores, and pellets of the meso-herbivores, were collected each month from November 2013 to April 2015 (excluding the flood period from June till October, during which the park remains closed and sample collection was not possible) (Yadava, 2014; Borah et al., 2018; Devi et al., 2022a). For elephant, buffalo, swamp deer, hog deer and sambar, the faecal samples were collected opportunistically, whereas, for rhino, the faecal samples were collected from latrine sites (De Barba et al., 2010). These faecal samples were collected from random locations in the short and tall grasslands, and woodlands within three forest ranges of KNP, namely Kohora (central), Agoratoli (eastern), and Bagori (western). Overall, 1975 faecal samples were collected for both mega- and meso-herbivores, of which 1500 samples were collected in the dry season (from November to March) and 475 samples in the wet season (April to May) (Appendix 9). For mega-herbivores, fresh dung samples, weighing about 400 gm each, was collected (Steinheim et al., 2005; Wegge et al., 2006). Based on the study by Jachmann and Bell (1984), which showed a positive linear relationship between elephant size, and weight and circumference of boli (individual faeces), boli was used as a guideline for elephant dung sample collection to ensure representation from varied body size individuals (Jachmann & Bell, 1984).

4.2.3 Sample Preparation

4.2.3.1 Reference plant sample

The reference samples were processed in the laboratory using the micro-histological technique (Kittur et al., 2007; Tiwari, 2009; Bhattacharya et al., 2012) (Figure 4.1 and Plate 3). The microscopic identification of forage plant fragments was carried out using the keys from Satkopan (1972) and Johnson et al. (1983) (Plate 4).

4.2.3.2 Faecal composite sample

The faecal samples collected from randomly selected habitats within similar locations and ranges were used to make composite samples. For mega-herbivores, five dung samples collected from the same location on the same date were selected randomly and mixed thoroughly to make one composite sample. From this composite sample, 25 gm of grounded dung sample was used for micro-histological analysis following Wegge et al (2006). Similarly, five faecal pellets of the meso-herbivores from each five randomly collected pellet samples were pooled together to make one composite sample. The composite samples were processed using the micro-histological technique following Wegge et al (2006) (Figure 4.1 and Plate 3).

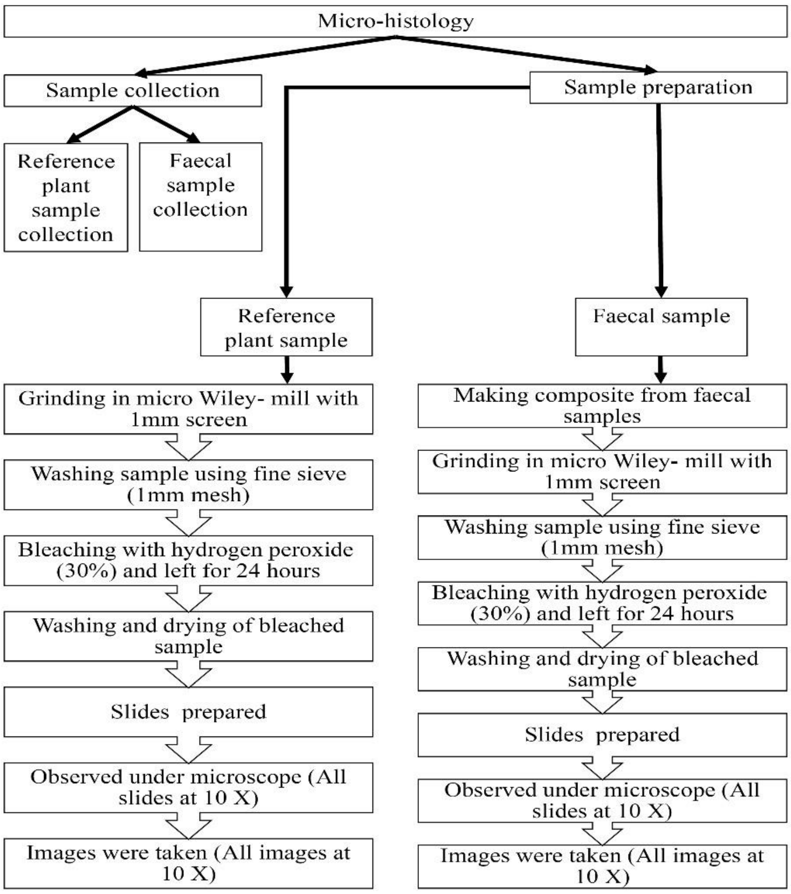


Figure 4.1. Pathway for micro-histological analysis of plant reference samples and faecal samples.

Five slides were prepared from each composite sample. Seventy composite samples and 350 slides each were prepared (no. of observations, n = 3500) for rhino and elephant. Sixty-five composite samples and 325 slides each were prepared for buffalo, swamp deer and hog deer (n = 3250), and 60 composite samples and 300 slides were prepared for sambar (n = 3000). Observations with at least two identifiable fragments were considered for the detection of forage plant species consumed. Whenever possible, identification up to the species level was attempted by comparing each sample with the reference plant samples. Only leaves, stems, flowers and fruit were taken for the preparation of reference materials, and not the bark or roots. Fragments with identifiable features where identification up to species or genus level was difficult due to damaged fragments were categorized as unidentified monocots (including *Bambusa* spp.), and unidentified dicots (including *Mallotus philippinensis*, *Terminalia* spp., and *Syzygium fruticosum*) (Pradhan et al., 2008).

4.2.4 Data Analysis

To determine the diet composition of mega- and meso-herbivores more precisely, the forage plants identified were categorized further on the basis of (1) graze-to-browse ratio (monocot and dicot consumption), (2) growth form (grasses, sedges, herbs, shrubs, climbers and trees), (3) family, and (4) species. The percentage occurrence of each forage type (graze-to-browse, growth forms, families and species) in the diet of mega- and meso-herbivores was determined using the equation by Sparks and Malechek (1968), and Tuboi and Hussain (2016):

$$\% \text{ contribution of forage plants} = \frac{Number\ of\ identifiable\ fragments\ of\ each\ category}{Total\ number\ of\ identifiable\ fragments\ of\ all\ plant\ species} \times 100$$

A species accumulation curve was plotted to determine the sampling effort required to adequately examine the diet composition of mega- and meso-herbivores. EstimateS version 9 with a 95% confidence interval was used to produce the species accumulation curve (Colwell & Elsensohn; 2014). The number of slides examined and the forage plants identified from the faecal samples of the mega- and meso-herbivores were plotted in the species accumulation curve (Colwell et al. 2012). The species accumulation curve was asymptotic at a sample size below the number of slides examined, indicating a sufficient sample size (Figure 4.2). Overall, rhino utilized the maximum number of forage species (n = 124, both identified and unidentified plants), followed by elephant (n = 105), buffalo (n = 96), sambar (n = 92), hog deer (n = 91), and swamp deer (n = 90) (Table 4.1).

The dietary spectrum of the mega- and meso-herbivores was obtained to visualize the pattern of forage utilization on the basis of the major contributing plants. The chi-square test of association and Fisher's Exact Test were carried out to identify seasonal differences in the forage consumed between the mega- and meso-herbivores and among the SLH. The tests were performed using SPSS version 22. The bipartite ecological network was used to visualize the forage utilization by mega- and meso-herbivores, using R package "bipartite" version 2.11 (Dormann et al., 2008). The forage plants were grouped by family, and only the top 20 abundant families, contributing more than 80% to the diet of mega- and meso-herbivores, were highlighted and the rest of the families were grouped under the other category.

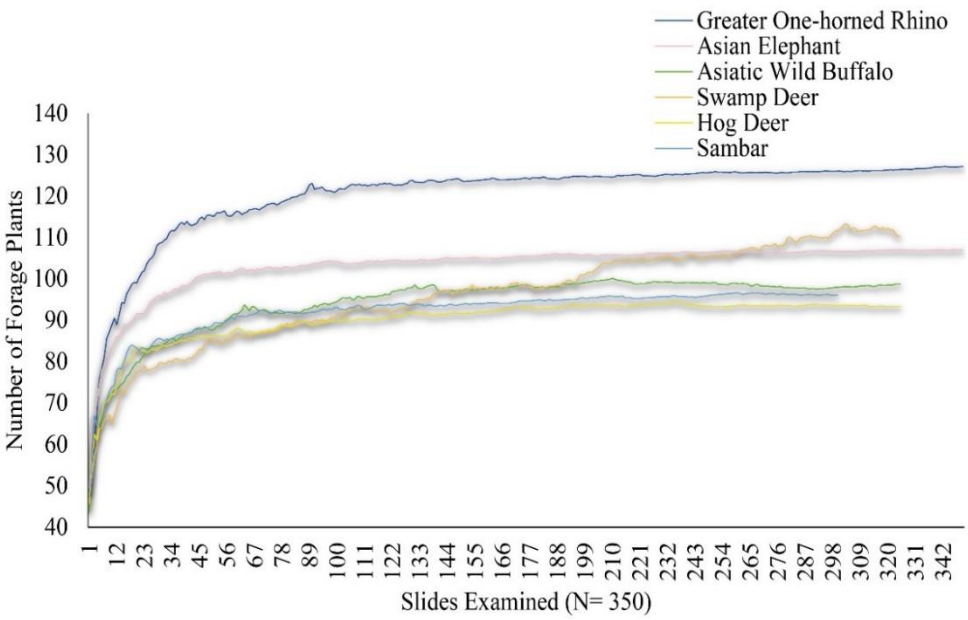


Figure 4.2. Overall species accumulation curve for mega- and meso-herbivores (Greater one-horned rhino and Asian elephant: N = 350; Asiatic wild buffalo, swamp deer and hog deer: N = 325; sambar: N = 300) in Kaziranga National Park, Assam, India.

4.3 Results

4.3.1 Diet Composition: Monocot and Dicot

In rhino dung samples, 8449 fragments were recorded, of which 88.99% (n = 7519) were identified up to genus and species, whereas 11.01% (n = 930) were unidentified (only identified up to monocot and dicot) (Table 4.1). Monocots constituted 57.13%, 56% and 59.68% of the rhino diet overall, and in the dry and wet seasons, respectively (Figure 4.3). And dicots constituted 42.87%, 44% and 40.32% of the rhino diet overall, and in the dry and wet seasons, respectively. In elephant dung samples, 8022 fragments were recorded, of which 89.55% (n = 7184) were identified up to genus and species and 10.45% (n = 838) were unidentified. Monocots constituted 53.54%, 50.73% and 60.43% of the elephant diet overall, and in the dry and wet seasons, respectively. And dicots constituted 46.46%, 49.27%, and 39.57% of the elephant diet overall, and in the dry and wet seasons, respectively. In buffalo dung samples, 7295 fragments were recorded, of which 87.77% (n = 6403) were identified up to genus and species and 12.23% (n = 892) were unidentified. Monocots constituted 62.60%, 61.51% and 66.38% of the buffalo diet overall, and in the dry and wet seasons, respectively. And dicots constituted 37.40%, 38.49%, and 33.62% of the buffalo diet overall, and in the dry and wet seasons, respectively.

In swamp deer pellet samples, 7475 fragments were recorded, of which 88.23% (n = 6595) were identified up to genus and species and 11.77% (n = 880) were unidentified. Monocots constituted 68.37%, 68.41%, and 68.26% of the swamp deer diet overall, and in the dry and wet seasons, respectively. And dicots constituted 31.63%, 31.59%, and 31.74% of the swamp deer diet overall, and in the dry and wet seasons, respectively. In hog deer pellet samples, 7359 fragments were recorded, of which 87.23% (n = 6419) were identified up to genus and species and 12.77% (n = 940) were unidentified. Monocots constituted 62.89%, 61.55% and 67.68% of the swamp deer diet overall, and in the dry and wet seasons, respectively. And dicots constituted 37.11%, 38.45%, and 32.32% of the hog deer diet overall, and in the dry and wet seasons, respectively. In sambar pellet samples, 7038 fragments were recorded, of which 89.19% (n = 6277) were identified up to genus and species, whereas 10.81% (n = 761) were unidentified. Monocots constituted 51.46%, 48.61% and 66.52% of the sambar diet overall, and in the dry and wet seasons, respectively. And dicots constituted 48.54%, 51.39%, and 33.48% of the sambar diet overall, and in the dry and wet seasons, respectively.

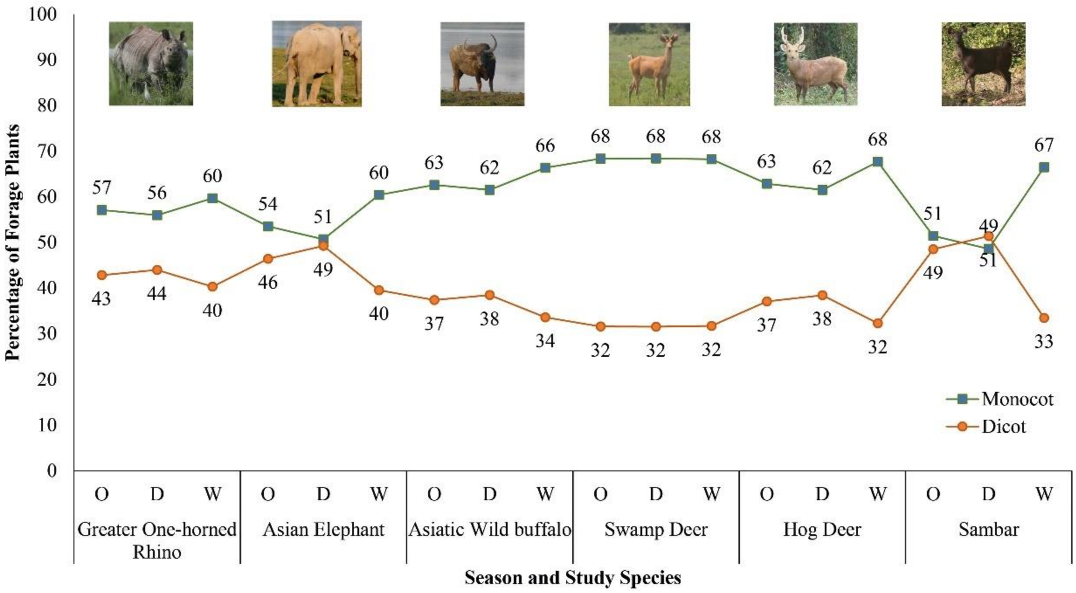


Figure 4.3. Graph showing overall and seasonal consumption of monocots and dicots by the six large herbivore species in Kaziranga National Park, Assam, India.

Mega- and meso-herbivores consumed more monocots during the wet season than in the dry season (Figure 4.3). Among SLH, there were significant seasonal differences in the consumption of monocots & monocots, dicots & dicots, and monocots & dicots (Table 4.2). Between the mega- and meso-herbivores, there were significant seasonal differences in the consumption of dicots & dicots and monocots & dicots, and no significant seasonal difference in the consumption of monocots & monocots.

Monocots dominated the diet of both mega- and meso-herbivores throughout the year. Only elephant and sambar consumed a significantly higher proportion of monocots than dicots in the wet season (Table 4.2). In contrast, there was no significant seasonal difference in the consumption of monocots & dicots by rhino, buffalo, swamp deer and hog deer. Compared to the dry season, the six herbivores consumed a significantly higher proportion of monocots and a significantly lower proportion of dicots in the wet season.

Table 4.1. Identified and unidentified fragments and forage plants recorded in the diet of mega- and meso-herbivores throughout the year during 2013-15 in Kaziranga National Park, Assam, India.

Study species	Fragments									Forage Plants				
	I	I %	UI	UI %	Total	M	M%	D	D%	I	I %	UI	UI %	Total
Greater One-horned Rhino	7519	88.99	930	11.01	8449	4827	57.13	3622	42.87	69	88.99	55	11.01	124
Asian Elephant	7184	89.55	838	10.45	8022	4295	53.54	3727	46.46	67	89.55	38	10.45	105
Asiatic Wild Buffalo	6403	87.77	892	12.23	7295	4567	62.60	2728	37.40	62	87.77	34	12.23	96
Swamp Deer	6595	88.23	880	11.77	7475	5111	68.37	2364	31.63	59	88.23	31	11.77	90
Hog Deer	6419	87.23	940	12.77	7359	4628	62.89	2731	37.11	59	87.23	32	12.77	91
Sambar	6277	89.19	761	10.81	7038	3622	51.46	3416	48.54	63	89.19	29	10.81	92

(I - identified; UI - unidentified; M - monocots; D - Dicots).

Table 4.2. Chi-square test between the dry and wet season (M- monocots; D- Dicots) food choice of the mega- and meso-herbivores during 2013-15 in Kaziranga National Park, Assam, India.

Forage category	Six Large Herbivores			Mega- and Meso-Herbivores			Greater One-horned Rhino			Asian Elephant			Asiatic Wild Buffalo			Swamp Deer			Hog Deer			Sambar		
	χ^2	df	p	χ^2	df	P	χ^2	df	p	χ^2	df	p	χ^2	df	p	χ^2	df	p	χ^2	df	p	χ^2	df	p
M & M	11.29	5	0.05	3.19	1	0.07	65.60	1	0.00	46.59	1	0.00	71.36	1	0.00	88.78	1	0.00	68.19	1	0.00	99.11	1	0.00
D & D	31.21	5	0.00	4.69	1	0.03	63.48	1	0.00	86.58	1	0.00	57.97	1	0.00	39.80	1	0.00	62.11	1	0.00	173.97	1	0.00
M & D	56.63	5	0.00	6.59	1	0.01	0.64	1	0.43	5.63	1	0.02	1.03	1	0.31	0.08	1	0.78	2.00	1	0.16	11.06	1	0.00
Grass	14.81	5	0.01	4.18	1	0.04	37.64	1	0.00	14.29	1	0.00	47.88	1	0.00	68.79	1	0.00	35.64	1	0.00	62.04	1	0.00
Herb	25.28	5	0.00	0.23	1	0.63	10.88	1	0.00	7.23	1	0.01	8.45	1	0.00	16.64	1	0.00	19.05	1	0.00	16.29	1	0.00
Tree	10.45	5	0.06	4.56	1	0.03	47.02	1	0.00	50.29	1	0.00	24.97	1	0.00	13.26	1	0.00	39.68	1	0.00	85.92	1	0.00
Sedge	2.44	5	0.79	1.34	1	0.25	8.33	1	0.00	37.69	1	0.00	15.51	1	0.00	4.55	1	0.03	3.46	1	0.06	21.56	1	0.00
Shrub	6.79	5	2.37	0.06	1	0.81	3.56	1	0.06	9.00	1	0.00	3.27	1	0.07	2.78	1	0.10	1.14	1	0.29	10.89	1	0.00
Climber	4.30	5	0.51	0.22	1	0.64	10.24	1	0.00	15.71	1	0.00	15.00	1	0.00	9.00	1	0.00	20.43	1	0.00	47.82	1	0.00
Saccharum spp (*)	16.62	5	0.01	1.61	1	0.21	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

*Principal forage of mega- and meso-herbivores

4.3.2 Diet Composition: Growth Form

Overall and in the dry season, among the six growth forms, grasses (35.68% and 34.92%) dominated the rhino diet, followed by herbs (24.58% and 25.73%), trees (9.79% and 9.88%), sedges (9.42% and 9.23%), shrubs (6.88% and 6.87%) and climbers (2.64% and 2.64%) (Figure 4.4). In the wet season, grasses (37.42%) dominated the rhino diet, followed by herbs (21.99%), sedges (9.86%), trees (9.59%), shrubs (6.88%) and climbers (2.78%). Overall, the elephant diet was dominated by grasses (29.53%), followed by herbs (19.09%), trees (15.47%), shrubs (14.55%), sedges (8.79%) and climbers (2.13%). In the dry season, the elephant diet mostly constituted of grasses (26.10%), followed by herbs (21.38 %), shrubs (16.41%), trees (15.08%), sedges (8.23%) and climbers (2.47%). In the wet season, the elephant diet was dominated by grasses (37.94%), followed by trees (16.43%), herbs (13.46%), sedges (10.15%), shrubs (9.98%) and climbers (1.29%). Overall, and in the dry and wet seasons, grasses (38.97%, 39.14% and 38.39%) dominated the buffalo diet, followed by herbs (21.11%, 21.03% and 21.39%), sedges (11.42%, 10.62% and 14.18%), trees (8.64%, 9.14% and 6.91%), shrubs (5.55%, 5.83% and 4.58%) and climbers (2.08%, 2.10% and 2.02%).

Overall, and in the dry and wet seasons, grasses (42.21%, 42.93% and 40.07%) dominated the swamp deer diet, followed by herbs (19.87%, 19.21% and 21.82%), sedges (15.33%, 14.77% and 16.99%), trees (7.24%, 7.37% and 6.85%), shrubs (3.24%, 3.47% and 2.55%) and climbers (0.35%, 0.38% and 0.27%). Overall, and in the dry and wet seasons, grasses (38.62%, 37.28% and 43.40%) dominated the hog deer diet, followed by herbs (20.15%, 21.19% and 16.44%), sedges (11.93%, 12.13% and 11.21%), trees (9.72%, 10.31% and 7.60%), shrubs (4.88%, 4.69% and 5.549%) and climbers (1.93%, 1.79% and 2.43%). Overall and in the dry season, among the six growth forms, grasses (31.37% and 29.69%) dominated the sambar diet, followed by herbs (24.44% and 25.80%), trees (13.95% and 14.71%), sedges (9.82% and 8.96%), shrubs (6.51% and 6.88%) and climbers (3.10% and 3.31%). In the wet season, grasses (40.25%) dominated the sambar diet, followed by herbs (17.28%), sedges (14.34%), trees (9.97%), shrubs (4.54%) and climbers (1.96%).

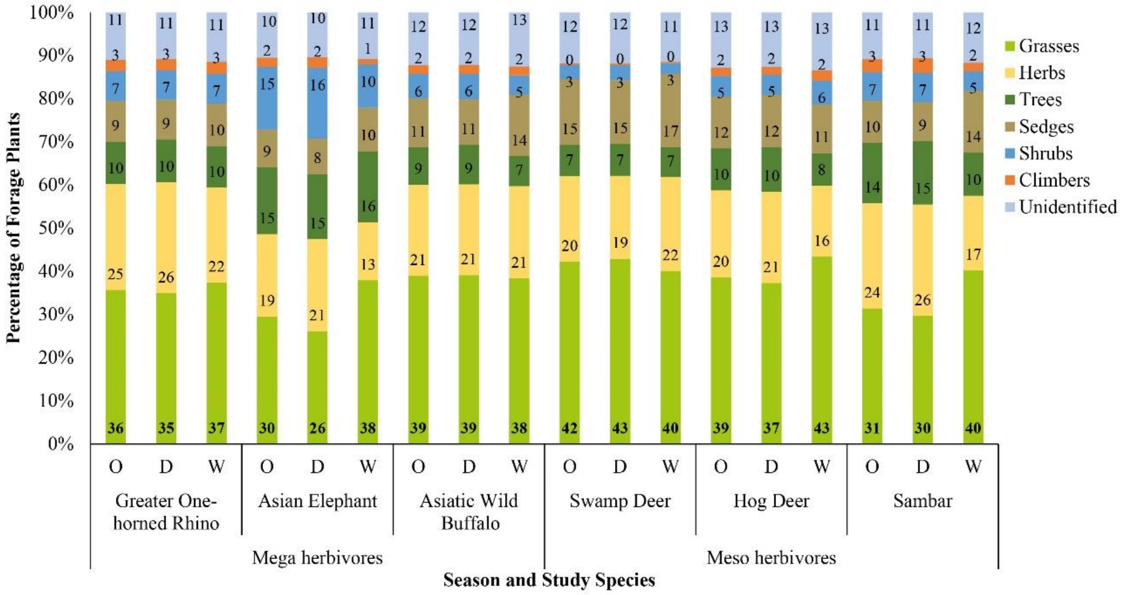


Figure 4.4. Graph showing diet composition of mega- and meso-herbivores in terms of six growth forms of different forage plants in Kaziranga National Park, Assam, India.

Among the six growth forms, grasses were dominant in the diet of all six herbivores (Figure 4.4). There were significant seasonal differences in the consumption of grasses and herbs among the SLH, and no significant differences in the consumption of sedges, shrubs, climbers and trees (Table 4.2). Between the mega- and meso-herbivores, there were significant seasonal differences in the consumption of grasses and trees, and no significant seasonal differences in the consumption of sedges, herbs, shrubs and climbers. Between the dry and wet seasons, the six herbivores consumed significantly different proportions of grasses, herbs, climbers and trees; and only elephant and sambar consumed a significantly different proportion of shrubs. Excluding hog deer, the study species consumed significantly different proportions of sedges (Table 4.2).

4.3.3 Diet Composition: Family

Overall, and in the dry and wet seasons, the rhino diet was composed of species belonging to 31, 29 and 30 families, respectively. Family Poaceae (35.68%, 34.92% and 37.42%) constituted the major portion of the rhino diet, whereas family Onagraceae (0.07%, 0.05%, and 0.12%) constituted the minimum portion, overall, and in the dry and wet seasons, respectively. Irrespective of season, the elephant diet was composed of species belonging to 30 families. Overall, in the dry and wet seasons, the family

Poaceae (29.53%, 26.10% and 37.94%) constituted the major portion of the elephant diet. In contrast, the species belonging to the family Apiaceae constituted the minimum portion of the elephant diet overall (0.16%) and in the dry season (0.19%), and the family Boraginaceae in the wet season (0.04%). Overall and in the dry season, the buffalo diet comprised of species belonging to 28 families, each, and 25 families in the wet season. Overall, and in the dry and wet seasons, the family Poaceae (38.97%, 39.14% and 38.39%) constituted the major portion of the buffalo diet. In contrast, species belonging to the family Boraginaceae constituted the minimum portion of the buffalo diet overall (0.03%) and in the wet season (0.02%), and the family Brassicaceae in the dry season (0.02%).

Overall and in the dry season, the swamp deer diet comprised of species belonging to 27 families, each, and 22 families in the wet season. Overall, and in the dry and wet seasons, the family Poaceae (42.21%, 42.93% and 40.07%) constituted the major portion of the swamp deer diet. Species belonging to the family Malvaceae, Cannabaceae and Brassicaceae constituted the minimum portion of the swamp deer diet overall (0.03%), and in the dry (0.04%) and wet seasons (0.16%), respectively. Irrespective of season, the hog deer diet was composed of species belonging to 26 families. Overall, and in the dry and wet seasons, the family Poaceae (38.62%, 37.28% and 43.40%) constituted the major portion of the hog deer diet. In contrast, species belonging to the family Onagraceae constituted the minimum portion of the hog deer diet overall (0.05%) and in the dry season (0.03%), and the family Malvaceae in the wet season (0.06%). Overall and in the dry season, the sambar diet comprised of species belonging to 29 families, each, and 27 families in the wet season. Overall, and in the dry and wet seasons, the family Poaceae (31.37%, 26.69%, and 40.25%) constituted the major portion of the sambar diet. In contrast, species belonging to the family Cleomaceae constituted the minimum portion of the sambar diet overall (0.01%) and in the dry season (0.02%), and the family Lauraceae in the wet season (0.09%).

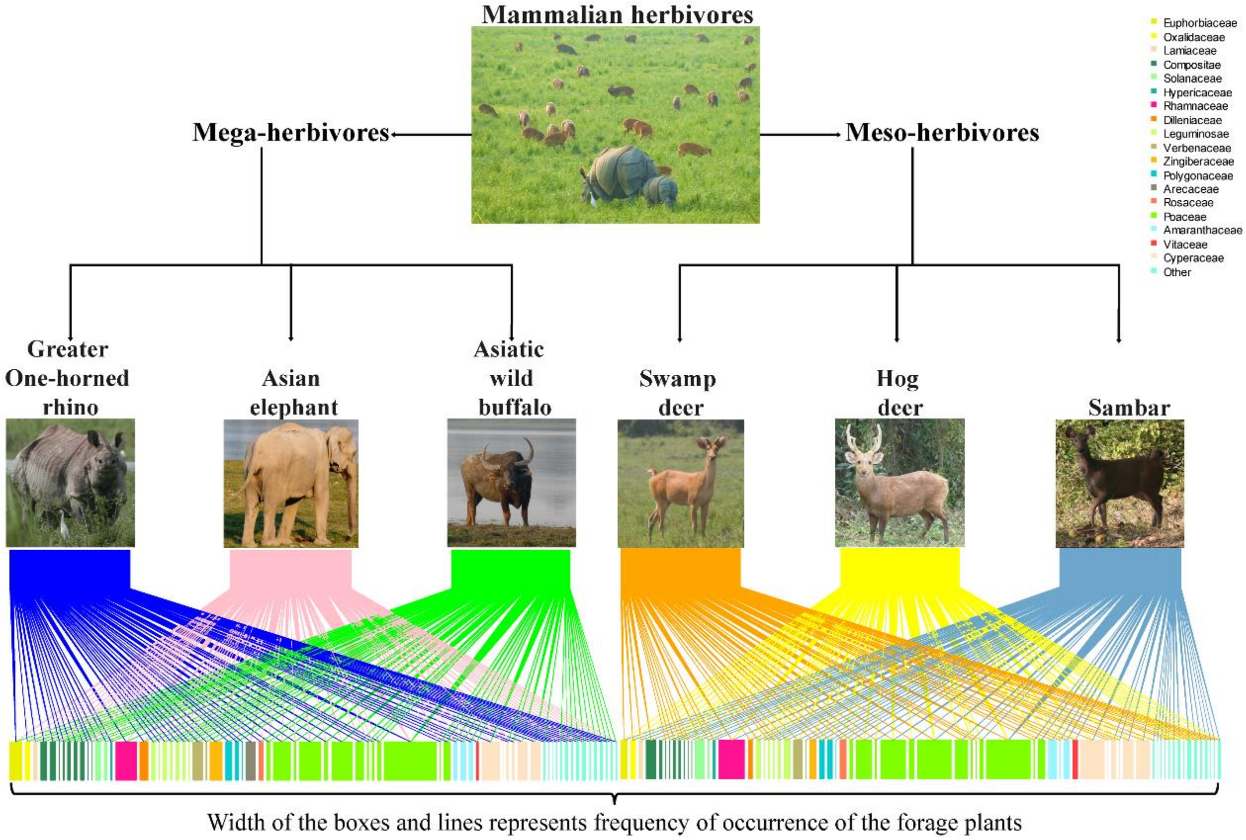


Figure 4.5. Flow diagram representing the overall bipartite ecological network, which illustrates the diet composition of mega- and meso-herbivores. Study species (upper boxes) connected by lines to forage plants (lower boxes) are coloured by family. The width of the lines and lower boxes represent the frequency of occurrence of the forage plants and their respective families in the diet of mega- and meso-herbivores in KNP, Assam, India.

A total of 31 families of forage plants were identified in the diet of the mega-herbivores and 29 in the diet of the meso-herbivores. Overall, the bipartite ecological network shows that the members of the family Poaceae contributed the most to the diet of mega- and meso-herbivores (Figure 4.5). It also shows that the contribution of forage species belonging to the families Poaceae and Cyperaceae, to the diet of both mega- and meso-herbivores, increased from dry (34.33% to 57.70%) to wet season (47.27% to 57.06%) (Figure 4.6a & 4.6b). *Calamus tenuis* (family Arecaceae) was consumed mostly by elephants. Bipartite ecological network further reveals that the mean number of shared forage plants in the diet of both mega- and meso-herbivores in the dry and wet seasons was 57.6 and 51, respectively.

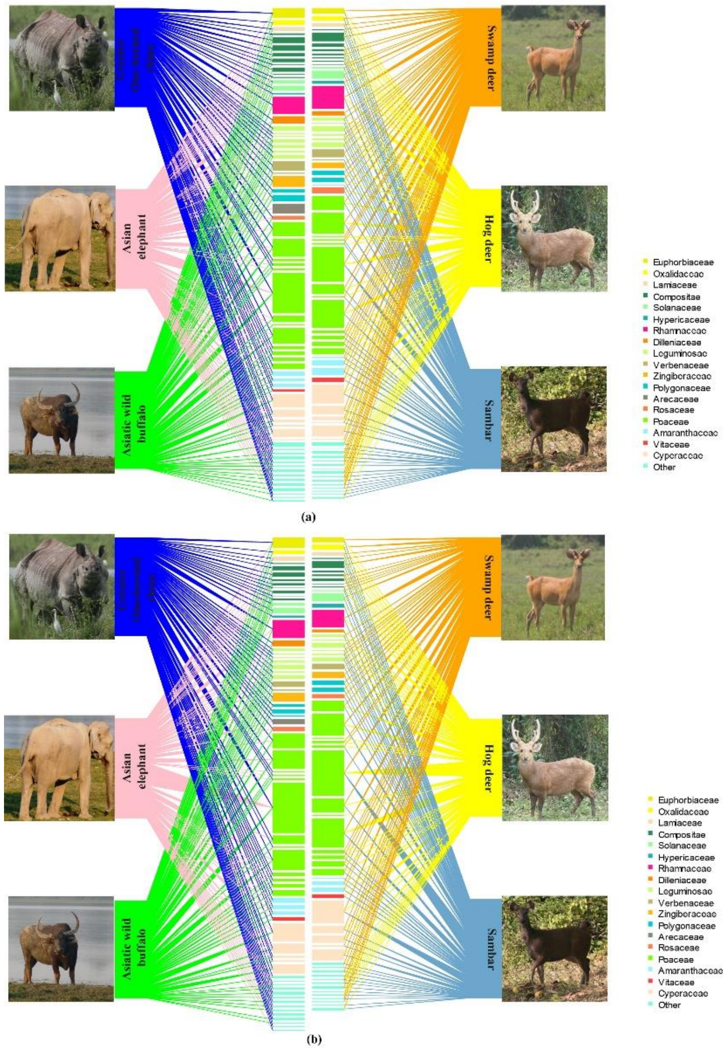


Figure 4.6. The bipartite ecological network illustrates the diet composition of mega and meso-herbivores. Study species (upper boxes) connected by lines to forage plants (lower boxes), which are coloured by family. The width of the lines and lower boxes represent the frequency of occurrence of the forage plants and their respective families in the diet of mega and meso-herbivores in (a) dry and (b) wet seasons in Kaziranga National Park, Assam, India.

4.3.4 Diet Composition: Plant Species

Throughout the year, 25 major forage plants constituted more than 70% of the diet of the large herbivores (Figure 4.7), specifically 79.48% of swamp deer, 75.87% of hog deer, 73.42% of sambar, 73.38% of buffalo, 71.04% of elephant, and 70.29% of rhino diet. The 22 principal forage plant species, namely *Saccharum* spp., *Echinochloa crus-*

galli, *Cynodon dactylon*, *Ziziphus jujuba*, *Hemarthria compressa*, *Alpinia nigra*, *Carex vesicaria*, *Kyllinga brevifolia*, *Mallotus nudiflorus*, *Lippia alba*, *Fimbristylis aestivalis*, *Amaranthus spinosus*, *Ageratum conyzoides*, *Duchesnea indica*, *Calamus tenuis*, *Oxalis corniculata*, *Imperata cylindrica*, *Acmella uliginosa*, *Amaranthus viridis*, *Dillenia indica*, *Solanum americanum* and *Setaria pumila* contributed more than 2% each. The highest number of identified principal forage species (n = 22) were recorded for hog deer (n = 14; 61.15%), followed by rhino (n = 13; 53.89%), elephant (n = 12; 55.00%), sambar (n = 12; 51.90%), buffalo (n = 11; 53.97%) and swamp deer (n = 11; 59.29%).

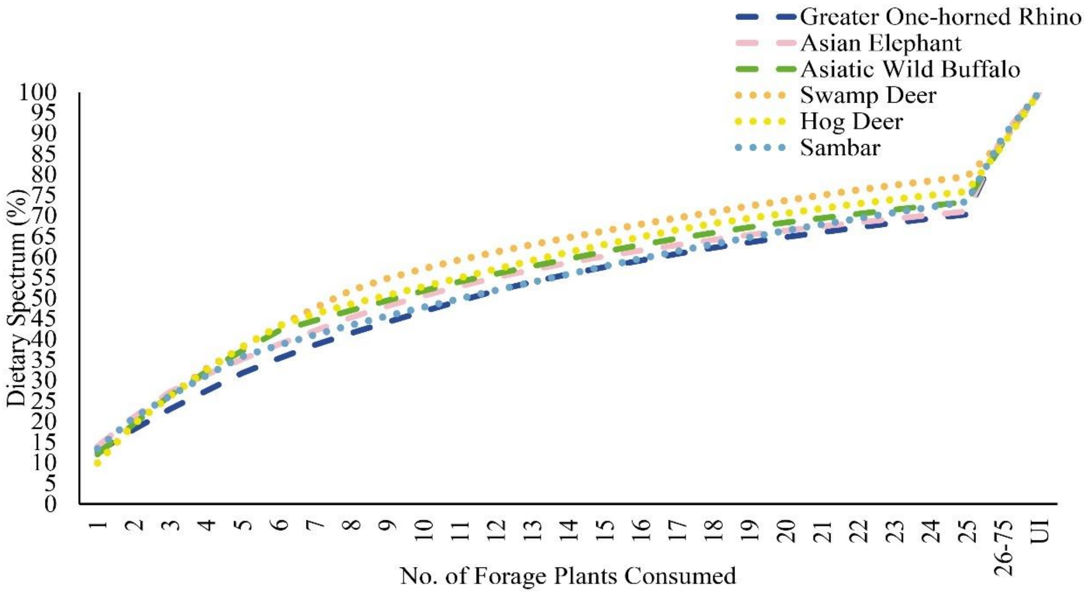


Figure 4.7. Graph showing overall dietary spectrum (%) of major contributing forage plants to the large herbivores diet in Kaziranga National Park, Assam, India.

Among the monocots, *Saccharum* spp., *E. crus-galli*, *C. dactylon*, *H. compressa* and *A. nigra* contributed the most to the rhino diet, while among the dicots, *Z. jujuba*, *M. nudiflorus*, *L. alba*, *A. spinosus* and *A. conyzoides* contributed the most (Appendix 10). In the elephant diet, *Saccharum* spp., *C. tenuis*, *C. vesicaria*, *E. crus-galli* and *H. compressa* contributed the most among the monocots, and *Z. jujuba*, *M. nudiflorus*, *D. indica*, *L. alba* and *A. conyzoides* contributed the most among the dicots (Appendix 11). In the buffalo diet, *Saccharum* spp., *H. compressa*, *E. crus-galli*, *C. vesicaria* and *C. dactylon* contributed the most among the monocots, and *Z. jujuba*, *O. corniculata*, *L. alba*, *S. americanum* and M. *nudiflorus* contributed the most among the dicots

(Appendix 12). In the diet of swamp deer, among the monocots, *H. compressa*, *Saccharum* spp., *E. crus-galli*, *C. vesicaria* and *I. cylindrica* contributed the most, and among the dicots, *Z. jujuba*, *A. uliginosa*, *L. alba*, *S. americanum* and *O. corniculata* contributed the most (Appendix 13). In the hog deer diet, *H. compressa*, *Saccharum* spp., *E. crus-galli*, *C. vesicaria* and *C. dactylon* contributed the most among the monocots, and *Z. jujuba*, *A. viridis*, *D. indica*, *S. americanum* and *L. alba* contributed the most among the dicots (Appendix 14). In the diet of sambar, among the monocots, *Saccharum* spp., *E. crus-galli*, *H. compressa*, *C. vesicaria* and *I. cylindrical* contributed the most, and among the dicots, *Z. jujuba*, *A. uliginosa*, *S. americanum*, *D. indica* and *M. nudiflorus* contributed the most (Appendix 15). The tall grass *Saccharum* spp. constituted a major part of the diet of mega- and meso-herbivores during the wet season. A significant seasonal difference in the consumption of *Saccharum* spp. was observed among the SLH, whereas no significant difference was observed in the consumption of *Saccharum* spp. between the mega- and meso-herbivores during different seasons.

4.4 Discussion

With their large body size, the rhino and elephant require almost 150 kg and 240 kg of fodder, respectively, every day, and thus spend most of their time foraging (Sukumar, 1989; Konwar et al., 2009; Johnsingh & Manjrekar, 2016). Both mega- and meso-herbivores consumed more monocots in the wet season than in the dry season, with the swamp deer consistently consuming more monocots than other herbivores species. An increase in graze from the dry to the wet season has been recorded in different studies, which also reported 22 to 283 forage plants in the diet of rhino (Pradhan et al., 2008; Dutta, et al., 2016), 46 to 112 forage plants in the diet of elephant (Sukumar, 1989; Pradhan et al., 2008; Baskaran et al., 2010), 183 forage plants in the diet of buffalo (Bawri and Saikia, 2014), 13 to 42 forage plants in the diet of swamp deer (Schaller, 1967; Wegge et al., 2006; Tewari & Rawat, 2013), and 15 to 20 forage plants in the diet of hog deer (Wegge et al., 2006; Tuboi & Hussain, 2016). The diet of sambar is flexible and changes according to the availability of forage (Kelton & Skipworth, 1987;

Semiadi et al., 1995), and studies have recorded 15 to 180 forage plants in the diet of sambar (Schaller, 1967; Johnsingh & Sankar, 1991).

In the present study, 124 forage plants in the diet of rhino were recorded of which 69 were identified up to species level and 55 were identified as monocots and dicots. For the elephant, 105 forage plants were recorded in the diet, of which 67 were identified up to species and 38 only as monocots and dicots. For buffalo, 96 forage plants were recorded in the diet, of which 62 were identified up to species and 34 only as monocots and dicots. For swamp deer, 90 forage plants were recorded in the diet, of which 59 were identified up to species and 31 only as monocots and dicots. For hog deer, 91 forage plants were recorded in the diet, of which 59 were identified up to species and 32 were only identified as monocots and dicots. For sambar, 92 forage plants were recorded in the diet, of which 63 were identified up to species and the remaining 29 only as monocots and dicots. The bipartite ecological network shows that in both the dry and wet seasons, graminoids constituted 50% or more of the diet of both mega- and meso-herbivores, with Poaceae and Cyperaceae as the most recorded families. In the family Poaceae, the tall grass *Saccharum* spp. was dominant, which might be because of its availability throughout the year. The diet of swamp deer and hog deer constituted more of the short grass species *H. compressa* in the dry season and more of the tall grass species *Saccharum* spp. in the wet season. *C. tenuis* (family Arecaceae) was mostly consumed by the elephant; a possible reason for this could be their ability to exploit resources that are not accessible to the other study species because of its trunk.

The presence of important fodder species, such as *Mallotus philippinensis*, could not be detected in the diet of any of our study species, even though it is common in the study area and evidence of browsing on it was observed. In other studies in similar habitats, its presence could not be detected in the diet of elephant, swamp deer and hog deer through faecal analysis (Pradhan et al., 2008, Wegge et al., 2006, and Steinheim et al., 2005). This is an inherent problem in study of feeding habits using micro-histological methods. Further, this study failed to detect the presence of *Bombax ceiba*, another common species in the area, though elephants eat its bark. In several other studies (e.g., Brahmachary et al.,1974 and Patar, 2005), it was concluded that the large herbivores do not eat *B. ceiba* leaves but debarking, particularly by elephants, is a common feature. A major proportion of the unidentified dicot forage in the diet can thus be attributed to woodland species like *M. philippinensis*, *Terminalia* spp., *Syzygium fruticosum, Mangifera indica* and *Ficus* spp. These are the reported forage species for rhino and elephant (Steinheim et al., 2005; Wegge et al.,2006; Pradhan et al.,2008; Konwar et al., 2009; Hazarika & Saikia, 2012).

Experimental studies conducted in North America and Europe showed that mega-herbivores meet their physiological needs by feeding more on dominant species. In a highly productive ecosystem, this favors plant diversity, whereas, in a low productive ecosystem, this negatively affects plant diversity (Bakker et al., 2006). In contrast, selective feeding by meso-herbivores negatively affects plant diversity (Edwards & Crawley, 1999). Therefore, feeding choices, population and physiological demand of mega- and meso-herbivores can alter the plant vegetation characteristics (Marquis, 2010). The present study revealed that throughout the year, among dicots, *Z. jujuba* was consumed the most by both mega- and meso-herbivores. Similarly, among monocots, *Saccharum* spp. was consumed the most by rhino, elephant, buffalo and sambar throughout the year. Whereas, *H. compressa* was largely consumed by swamp deer, and hog deer. This suggests the dependence of mega- and meso-herbivores on these particular dicots and monocots. In the future, any changes in the availability and accessibility of the major forage plants might affect the population of these mega- and meso-herbivores. Therefore, further experimental studies explaining the factors responsible for feeding choices as well as the impact of mega- and meso-herbivores on plant vegetation, are required to understand the community vegetation dynamics in Kaziranga.

4.5 Conclusion

The information on diet composition provides insight into the feeding habits of select mega- and meso-herbivores in the riverine alluvial grasslands of the Brahmaputra floodplains. The findings of this study revealed that mega- and meso-herbivores grazed more during the wet season, although browse also formed a significant portion of the diet; indicating that both mega- and meso-herbivores were grazers and mixed feeders. Possibly due to the availability of green and nutrient-rich forage, the higher moisture regime and the controlled burning of wet grasslands, both mega- and meso-herbivores feed more on monocots in the wet season (Pradhan et al., 2008). As monocots were dominant in the forage of rhino, buffalo, swamp deer and hog deer throughout the year, these study species may be more involved in grazing during both the dry and wet seasons. The shifting of elephant and sambar in the wet season from browsing to grazing indicates their flexibility in the utilization of available forage. Compared to other herbivores, the diet of rhino, elephant and sambar consisted more of browse. This contradicts the Jarman-Bell principle, according to which large-bodied herbivores act as bulk and coarse feeders, by feeding on less nutritious graminoids. The seasonal changes in forage availability, mouth size, gut physiology and predation risk might be responsible for the differences in the forage consumption among mega- and meso-herbivores as observed in other studies (e.g., Steinheim et al., 2005; Wegge et al., 2006; Pradhan et al., 2008). The study suggests that both tall and short grasses play a crucial role in meeting the dietary requirements of SLH, and highlights the importance of riverine alluvial floodplain grasslands in conserving these herbivores. In KNP, the ongoing processes of succession and invasion threaten the grasslands, which in the future might affect the availability of the principal forage plants consumed by mega- and meso-herbivores. Thus, grassland-based effective management interventions for conserving this crucial habitat of mega- and meso-herbivores are suggested. In the climate crisis and habitat degradation era, the present study will help park managers in formulating effective conservation strategies for the mega- and meso-herbivores.

CHAPTER 5
FORAGE PREFERENCE AND DIET OVERLAP AMONG SIX LARGE HERBIVORES

Summary

Ecological niche partitioning is fundamental for the coexistence of sympatric species. However, the relationship between herbivore body size and forage availability on resource segregation and selection remains debatable. This study quantifies niche differentiation and selectivity in terms of forage species consumed by six large herbivores (SLH), specifically three mega-herbivores viz., rhino, elephant, and buffalo, and three meso-herbivores viz., swamp deer, hog deer, and sambar, in the riverine alluvial grasslands of Kaziranga National Park (KNP), Assam, India. Herbivore foraging patterns were quantified using micro-histological analysis of faecal samples (N=1975), forage availability using the harvest method and herbivores' preference by Jacob's index. Dietary similarities and dissimilarities among the herbivores were estimated using Schoener Index (SI), Non-metric Multidimensional Scaling (NMDS), Analysis of similarities (ANOSIM) and Similarity in Percentages (SIMPER).

Compared to the dry season (1354.54±641.30 g m^{-2}), significantly higher mean biomass was recorded in the wet season (3026.93±1632.65 g m^{-2}; $p<0.05$). Grasses contribute the most to biomass. Throughout the year, dicot was the most preferred forage of the elephant, and monocot of swamp deer and sambar. From dry to wet season, rhino, buffalo and hog deer shifted their preferred forage from dicot to monocot. Invasives *Merremia umbellata* and *Mimosa* spp. were avoided by SLH and *Mikania micrantha* by meso-herbivores. Among SLH, high dietary overlap was recorded between buffalo and hog deer (0.79-0.86), and swamp deer and hog deer (0.75-0.86), among mega-herbivores between rhino and buffalo (0.80-0.83), and among meso-herbivores between swamp deer and hog deer (0.75-0.86). Among SLH, high dietary dissimilarity was recorded between elephant and swamp deer (36-37%), among mega-herbivores between elephant and buffalo (27-33%), and meso-herbivores between swamp deer and sambar (27-29%).

In conclusion, from dry to wet season, there is a significant increase in forage biomass, probably due to precipitation. Forage availability contributes to the forage preference by herbivores, and invasives have the potential to impact foraging ecology. Irrespective of season, biologically significant dietary overlap (>0.6) was recorded among SLH due to sufficient forage availability. Additionally, differences in the foraging strategies and resource segregation at a spatio-temporal scale may also be a possible reason for the significant dietary overlap. Forage segregation, despite being challenging to interpret at the taxonomic level, influences niche partitioning among mega- and meso-herbivores.

5.1 Introduction

Niches are the hyper-dimensional indices that describe resource use by a species (Hutchinson, 1957). Resource-utilization concept suggests that two species cannot occupy a similar niche in a similar environment over long time scales without competition, which might result in the local extinction of other species (Hardin, 1960; MacArthur & Levins, 1967). In contrast, ecological niche partitioning, one of the fundamental principles used in community ecology, predicts that sympatrically occurring species partition their resources spatially or temporally to coexist without competition (Pianka, 1969; Schoener, 1974). The coexisting species are expected to show natural selection by evolving themselves for niche partition in limited resource conditions (MacArthur & Levins, 1967). The knowledge and understanding of resource selection and partitioning are integral to understanding plant-animal interactions (Marquis, 2010).

The niche overlap with respect to the diet provides insight into the shared use of forage resources between two or more species (Pianka, 1973 & 1974). In sympatrically occurring large herbivore systems, diets often overlap to large extents due to the consumption of mutual forage species and plant parts. Information on diet overlap among large herbivores may help to formulate the assumption of how they partition the resources. A high degree of dietary overlap could indicate competition only in case of limited resources (Sale, 1974; Terborgh, 1983). Although, in limited resource conditions, large herbivores were found to reduce competition by spatial and temporal partitioning of the resources (Pianka, 1974; Durso et al., 2013). Therefore, resource use overlap in terms of habitat and diet is a useful approach to understanding resource utilization patterns (Schoener, 1974; Jones & Barmuta, 1998; Mysterud, 2000), and can provide insight into potential competition (Abrams, 1980).

Large herbivores, once abundant in Africa and Asia, are now disappearing at an alarming rate. They are now restricted to the protected areas of Africa and Asia, majorly due to anthropogenic pressures like habitat fragmentation, over-exploitation and poaching (Lamprey & Reid, 2004; Pradhan et al., 2008; Sukumar, 2012). Anthropogenic pressures influence the forage and space available for herbivores and restrict the population to a particular area (Pradhan et al., 2008). This makes forage and space the primary concern of animals for their survival and reproduction. In such scenarios, information on the foraging and resource utilization pattern of a guild becomes an important factor that provides insight into the community ecology of a species (Ahrestani et al., 2016). The large-bodied herbivores require more food and space compared to small-bodied herbivores (Owen-Smith, 1988; Pradhan et al., 2008). However, forage selection is not only guided by the body sizes of the large herbivore species, but also includes the composition, quantity and quality of forage species (Bell, 1971; Jarman, 1974; Gordon & Illius, 1996; Ahrestani & Sankaran, 2016). With difference in the availability of forage species and their nutritive content, the consumption and selection of plant species are also affected (Van Soest, 1996; Ahrestani et al., 2009). Thus, it is important to provide insights into how large- and small-bodied herbivores select the forage species available to them.

Knowledge and understanding of the community ecology of mega- and meso-herbivores are crucial for effectively managing herbivores and their associated habitat. KNP in the Brahmaputra floodplains provides the opportunity to examine the community ecology of mega- and meso-herbivores in an ecosystem subject to human pressure and susceptible to climate change. Thus, the present study was conducted in KNP and focused on six large herbivores (SLH) of different body sizes, specifically the mega-herbivores ─ Greater one-horned rhino (*Rhinoceros unicornis*), Asian elephant (*Elephas maximus*) and Asiatic wild buffalo (*Bubalus arnee*), and the meso-herbivores ─ swamp deer (*Rucervus duvaucelii*), hog deer (*Axis porcinus*) and sambar (*Rusa* *unicolor*). Results from the previous chapter revealed that these large herbivores act as grazers and mixed feeders in KNP, which results in considerable seasonal variation in consumed food items (Devi et al., 2022a). These variations in foraging patterns can be influenced by body size, interactions like competition and predation, resource availability, plant height, nutrient content, gut physiology and herbivores' distribution (Pansu et al., 2019). Knowledge and understanding of the resource utilization pattern and preference for forage species provide insight into prey-predator dynamics. In view of this, the chapter aims to provide answers to the following research questions:

1) What are the most preferred forage species in the diet of SLH in the dry and wet seasons?
2) What is the similarity and dissimilarity in SLH diet, and which forage species contribute the most to diet dissimilarity?

5.2 Methodology

5.2.1 Forage Preference

5.2.1a Forage availability

The aboveground biomass was estimated using the harvest method from January 2014 to July 2015 (except for the flood season from August to October) (Tuboi & Hussain, 2016). Ten enclosures of 10m × 10m were constructed in the grasslands, and the aboveground plants were harvested from 1m × 1m plots in three monthly replicates. Overall, 540 plots were harvested, of which 300 were harvested during the dry season and 240 during the wet season. The fresh clipped plants were sorted by species and weighed to record their wet weight, then oven-dried at 60 °C to record their dry weight. The biomass of the plant species was calculated from the differences recorded between the wet and dry weights of the individual plant. Based on the forage plant consumption of mega- and meso-herbivores, only the biomass of 35 identified forage species consumed that occurred in the plots was calculated. For 35 forage plants, the biomass was also calculated in terms of the six growth forms: grasses, sedges, herbs, shrubs, climbers and trees. A non-parametric Mann-Whitney Test was performed to test the significant differences between the dry and wet season biomass. To calculate the forage preference of mega- and meso-herbivores, only forage that contributed more than 1% to the biomass was considered.

Glimpses of vegetation in the Kaziranga National Park, Assam, India.

5.2.1b Forage preference index

The forage selectivity was examined in terms of forage species utilized more or less than their availability in the environment. The updated version of Ivlev's electivity Index, Jacob's Index, was used to examine the forage selection and strength of forage selection of mega and meso-herbivores. Jacob's index was estimated using the following formula (Jacob, 1974):

$$D = \frac{(r_i - p_i)}{(r_i + p_i - 2r_ip_i)}$$

where D represents Jacob's forage selectivity index, r_i the proportion of i forage plant in the diet of mega- and meso-herbivores, and p_i the proportional availability of i forage species in the environment. The value of D ranges from -1 to +1, where -1 (avoidance) indicates the utilization of forage species less than its availability, +1 (preference) indicates the utilization of forage species more than its availability, and 0 represents non-selective feeding on forage species, which predicts that forage species were consumed in proportion to their availability (Jacob, 1974). Bonferroni simultaneous confidence interval approach was used to test the difference between the availability of forage species in the environment (proportion of available forage) and the diet of the study species (proportion of used forage) (Byers et al., 1984; Spencer et al., 2014).

The forage species were considered to be avoided i.e., used less than its availability, only if the proportion of available forage species lies above the confidence level estimated for its proportion of occurrence in the diet, whereas forage species were considered to be preferred i.e., used more than its availability, only if the proportion of available forage species fell below the confidence level estimated for its proportion of occurrence in the diet (Neu et al., 1974; Byers et al., 1984; Spencer et al., 2014).

5.2.2 Diet Overlap

5.2.2a Faecal sample collection and micro-histology

The dietary composition of mega- and meso-herbivores was examined using the micro-histology technique (Sparks & Malechek, 1968; Tuboi & Hussain, 2016; Devi et al., 2022a). This technique involves the preparation of plant reference slides (leaves, stems, flowers, and fruits) and their comparison to slides prepared from the faecal samples of known herbivore species (Sparks & Malechek, 1968). The plant fragments in faeces were identified based on each forage plant’s epidermal and cellular characteristics to further estimate the frequency of occurrence of various forage fragments (Devi et al., 2022a). Keys from Satkopan (1972) and Johnson et al. (1983) were referred to identify plant fragments at the microscopic level. Based on literature review and field observations, 75 reference plants were collected, oven-dried at 60°C for ~48 hours, kept in systematically labelled paper bags, and transported to the base for micro-histological analysis (Devi et el., 2022a). The reference plant materials were identified taxonomically using Hajra and Jain (1994).

For micro-histological examination, the fresh faecal samples of mega- and meso-herbivores were collected from November 2013 to April 2015 (except the flood season from June to October) (Devi et al., 2022a). During the field survey, 1975 faecal samples were collected, of which 350 faecal samples were of rhino and elephant, each, 325 each of buffalo, swamp deer and hog deer, and 300 of sambar. In the dry (November to March) and wet (April to May) seasons, 1500 and 475 faecal samples were collected, respectively (Appendix 9). The faecal samples were oven-dried at 60 ℃ for 48 hours and grounded in a Micro-Willey mill (Devi et al., 2022a). Five random faecal samples collected from similar locations and dates were mixed together to make one composite sample. About 25 gm of each composite sample was used for the micro-histological analysis (Devi et al., 2022a). Five slides were prepared from each composite sample, which were observed under the microscope at 150X magnification. Observation fields with at least two identifiable fragments were considered for identification (Pradhan et al., 2008). Both identified and unidentified fragments were recorded to determine their frequency of occurrence in the faecal sample (Sparks & Malcheck, 1968).

5.2.2b Similarity and dissimilarity in the diet

The multivariate diet analysis was carried out using non-metric multidimensional scaling (NMDS) to visualize diet overlap. The Bray-Curtis similarity matrix was used to examine the degree of similarity and dissimilarity in the forage utilization of SLH, mega-herbivores and meso-herbivores (Kartzinel et al., 2015). For three-dimensional NMDS, study species were treated as samples and forage species as variables. In the NMDS ordination plot, the samples were segregated based on their dissimilarity. Therefore, representing similar samples with close vicinity and dissimilar samples with separation. Following NMDS, permutational multivariate analysis of variance (permANOVA), a permutation-based non-parametric test with 999 permutations, was performed to test the significance of differences within SLH, mega-herbivores and meso-herbivores (Anderson & Walsh, 2013). The analysis was carried out in statistical software R (version 3.5.1) using the package “vegan”. For the NMDS plot and permANOVA, function metaMDS (version 2.5-2) and function adonis of the package “vegan” was used, respectively (Oksanen et al., 2011).

Schoener Index (SI) was used to examine diet overlap among SLH (Schoener, 1970; Mabragana & Giberto, 2007). SI ranges from zero (no overlap) to one (complete overlap) (Mabragana & Giberto, 2007). SI more than 0.6 indicates biologically significant diet overlap (Mabragana & Giberto, 2007):

$$SI = 1 - 0.5(\sum_{i=1}^{n} |p_{iA} - p_{iB}|)$$

where p_{iA} represents the frequency of occurrence of i^{th} plant species utilized by herbivore species A and p_{iB} represents the occurrence of i^{th} plant species utilized by herbivore species B (Schoener, 1970; Mabragana & Giberto, 2007). SI was estimated using the function niche.overlap of package "spaa" (version 0.2.2) in statistical software R (version 3.5.1) (Zhang, 2013).

The rank-based permutation test, one-way analysis of similarities (ANOSIM), was used to test the null hypothesis of no significant difference in forage utilized by SLH. Two-way ANOSIM test was used to test the null hypothesis of no significant difference in seasonal forage utilized by SLH. ANOSIM with 999 permutations and Bray Curtis distance was performed (Clarke, 1993; Cupples et al., 2011). The global R statistics in ANOSIM, ranging from 0 to 1, represents the degree of similarity to dissimilarity, respectively (Clarke, 1993; Mabragana & Giberto, 2007; Anderson & Walsh, 2013). The R statistics <0.25, 0.26-0.5 and >0.5 represent high, medium and low overlap, respectively (Gkenas et al., 2019). If the result from ANOSIM was significant ($p \leq 0.001$), then similarity in percentages (SIMPER) was used to examine the forage species contributing the most to the dissimilarity in the diet among SLH. The analysis of ANOSIM and SIMPER was carried out using the statistical software Past3 (Hammer et al., 2001).

5.3 Results

5.3.1 Forage Availability

Mean biomass of 4381.47±2268.4 g m^{-2} was recorded throughout the year, 1354.54±641.30 g m^{-2} in the dry season and 3026.93±1632.65 g m^{-2} in the wet season (Table 5.1). Between the dry and wet seasons, there was a significant difference in mean biomass (Mann–Whitney, $p<0.05$) (Table 5.2). Compared to other growth forms, the highest mean biomass was recorded for grasses throughout the year (6607.17±931.74

g m^{-2}), and in both the dry (3595.24±508.63 g m^{-2}) and wet (10372.09±826.5 g m^{-2}) seasons (Figure 5.1). Between dry and wet seasons, there was a significant difference among the mean biomass of the six growth forms (Kruskal-Wallis H=194.38, df=5, $p<0.05$). There were significant seasonal differences only in the mean biomass of grasses & grasses, herbs & herbs (Mann–Whitney, $p<0.05$) and no significant seasonal difference in the biomass of sedges & sedges, climbers & climbers, shrubs & shrubs and trees & trees (Mann–Whitney, $p>0.05$). Irrespective of season, tall grass *Saccharum* spp. and short grass *Hemarthria compressa* contributed the most to available forage biomass (Table 5.1). Of the 35 forage species, only 11 *viz*., *Alpinia nigra*, *Carex vesicaria*, *Cynodon dactylon*, *Flemingia lineata*, *H. compressa*, *Litsea salicifolia*, *Merremia umbellata*, *Mikania micrantha*, *Mimosa* spp., *Paspalum conjugatum*, and *Saccharum* spp. contributed more than 1% to forage biomass.

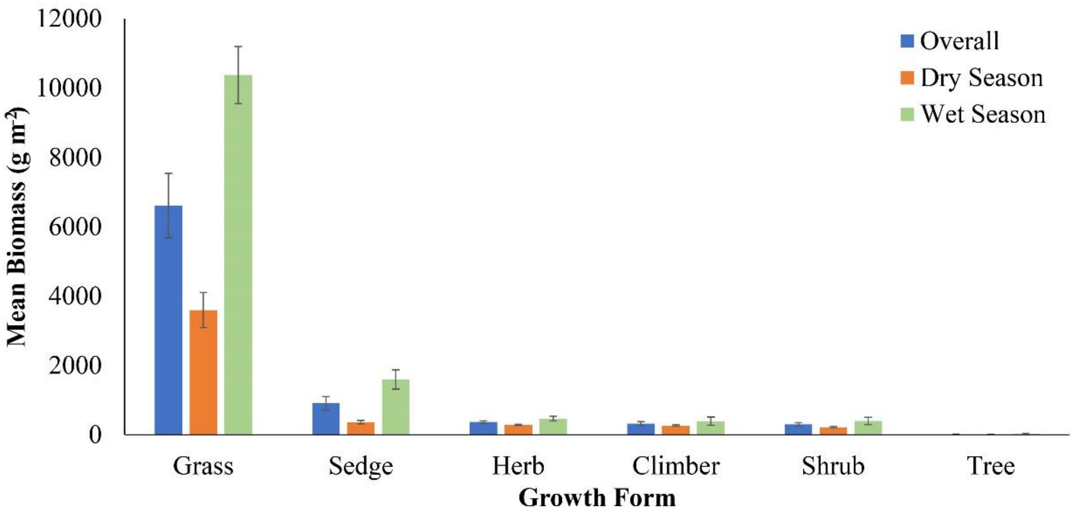


Figure 5.1. Graph showing the forage biomass of different growth forms in Kaziranga National Park, Assam, India.

Table 5.1. Biomass of the forage species in Kaziranga National Park, Assam, India.

Forage species	Growth Form	Overall Biomass			Dry Season Biomass			Wet Season Biomass		
		TB	MB	%	TB	MB	%	TB	MB	%
Cynodon dactylon (L.) Pers.	Grass	15398.57	855.48±101	10.04	5902.23	590.22±83.85	12.45	9496.33	1187.04±127.18	8.96
Echinochloa crus-galli (L.) P.Beauv.	Grass	18.2	1.01±0.31	0.01	11.1	1.11±0.4	0.02	7.1	0.89±0.51	0.01
Hemarthria compressa (L.f.) R.Br.	Grass	26602.7	1477.93±196.07	17.35	8693.48	869.35±126.78	18.34	17909.22	2238.65±188.21	16.9
Imperata cylindrica (L.) Raeusch.	Grass	30.2	1.68±0.79	0.02	7.04	0.7±0.7	0.01	23.16	2.89±1.49	0.02
Paspalum conjugatum P.J.Bergius	Grass	1611.64	89.54±22.99	1.05	587.73	58.77±21.8	1.24	1023.91	127.99±41.78	0.97
Saccharum spp.	Grass	74363.01	4131.28±642.95	48.49	20477.73	2047.77±319.4	43.19	53885.28	6735.66±592.22	50.86
Setaria pumila (Poir.) Roem. & Schult.	Grass	904.78	50.27±11.72	0.59	273.03	27.3±14.47	0.58	631.74	78.97±14.24	0.6
Total Grass		**118929.1**	**6607.17±931.74**	**77.55**	**35952.35**	**3595.24±508.63**	**75.83**	**82976.74**	**10372.09±826.5**	**78.32**
Carex vesicaria L.	Sedge	16340.08	907.78±189.86	10.66	3643.44	364.34±49.51	7.69	12696.63	1587.08±272.71	11.98
Kyllinga brevifolia Rottb.	Sedge	57.99	3.22±1.75	0.04	6.62	0.66±0.66	0.01	51.37	6.42±3.66	0.05
Total Sedge		**16398.06**	**911±191.25**	**10.69**	**3650.06**	**365.01±49.71**	**7.7**	**12748**	**1593.5±275.89**	**12.03**
Acmella uliginosa (Sw.) Cass.	Herb	25.98	1.44±0.85	0.02	15.6	1.56±1.38	0.03	10.38	1.3±0.93	0.01
Ageratum conyzoides (L.) L.	Herb	94.46	5.25±2.65	0.06	17.31	1.73±0.87	0.04	77.14	9.64±5.67	0.07
Alpinia nigra (Gaertn.) Burtt	Herb	4877.97	271±29.06	3.18	2304.15	230.42±18.7	4.86	2573.81	321.73±58.23	2.43
Chenopodium album L.	Herb	51.49	2.86±1.59	0.03	15.52	1.55±1.55	0.03	35.97	4.5±3.04	0.03
Cotula hemispherica (Roxb.) Raizada	Herb	26.95	1.5±1.47	0.02	0.47	0.05±0.05	0	26.49	3.31±3.31	0.03
Duchesnea indica (Andrews) Focke	Herb	10.17	0.57±0.21	0.01	3.29	0.33±0.25	0.01	6.88	0.86±0.35	0.01
Grangea maderaspatana (L.) Poir.	Herb	468.73	26.04±4.94	0.31	153.99	15.4±3.64	0.32	314.74	39.34±8.17	0.3
Heliotropium indicum L.	Herb	216.48	12.03±2.78	0.14	89.91	8.99±3.37	0.19	126.57	15.82±4.48	0.12
Laphangium luteoalbum (L.) Tzvelev	Herb	33.92	1.88±0.88	0.02	8.96	0.9±0.38	0.02	24.96	3.12±1.89	0.02
Ludwigia adscendens (L.) H.Hara	Herb	114.25	6.35±1.9	0.07	15.13	1.51±1.2	0.03	99.13	12.39±2.83	0.09
Oxalis corniculata L.	Herb	22.03	1.22±0.66	0.01	2.32	0.23±0.23	0	19.71	2.46±1.37	0.02
Persicaria hydropiper (L.) Delarbre	Herb	128.84	7.16±2.34	0.08	31.71	3.17±1.5	0.07	97.13	12.14±4.46	0.09
Polygonum plebeium R.Br.	Herb	159.32	8.85±2.14	0.1	69.35	6.93±2.1	0.15	89.97	11.25±4.05	0.08
Rorippa indica (L.) Hiern	Herb	249.3	13.85±4.03	0.16	96.67	9.67±2.96	0.2	152.63	19.08±8.23	0.14
Xanthium strumarium L.	Herb	116.06	6.45±2.6	0.08	51.62	5.16±2.14	0.11	64.44	8.05±5.38	0.06
Total Herb		**6595.95**	**366.44±38.37**	**4.3**	**2876**	**287.6±18.84**	**6.07**	**3719.95**	**464.99±70.54**	**3.51**

Forage species	Growth Form	Overall Biomass			Dry Season Biomass			Wet Season Biomass		
		TB	MB	%	TB	MB	%	TB	MB	%
Merremia umbellata (L.) Hallier f.	Climber	4160.45	231.14±44	2.71	1668.95	166.9±26.6	3.52	2491.5	311.44±88.22	2.35
Mikania micrantha Kunth	Climber	1582.27	87.9±19.07	1.03	958.12	95.81±21.38	2.02	624.15	78.02±35.04	0.59
Tetrastigma dubium (Lawson) Planch.	Climber	67.45	3.75±1.68	0.04	36.46	3.65±2.6	0.08	30.98	3.87±2.11	0.03
Total Climber		**5810.16**	**322.79±54.19**	**3.79**	**2663.54**	**266.35±21.6**	**5.62**	**3146.63**	**393.33±118.38**	**2.97**
Flemingia lineata (L.) Aiton	Shrub	1275.26	70.85±14.52	0.83	646.37	64.64±13.52	1.36	628.89	78.61±29.04	0.59
Flueggea virosa (Roxb. ex Willd.) Royl	Shrub	832.01	46.22±15.71	0.54	353.39	35.34±13.41	0.75	478.61	59.83±31.81	0.45
Lippia alba (Mill.) N.E.Br. ex Britton & P.Wilson	Shrub	408.13	22.67±10.62	0.27	49.19	4.92±1.77	0.1	358.94	44.87±22.02	0.34
Litsea salicifolia (Roxburgh ex Nees) Hook. f.	Shrub	1126.35	62.58±16.08	0.73	487.47	48.75±13.8	1.03	638.89	79.86±32.1	0.6
Mimosa spp.	Shrub	1505.23	83.62±19.44	0.98	569.42	56.94±15.09	1.2	935.81	116.98±37.6	0.88
Solanum viarum Dunal	Shrub	41.22	2.29±1.3	0.03	37.39	3.74±2.26	0.08	3.84	0.48±0.48	0
Stachytarpheta indica (L.) Vahl	Shrub	174.96	9.72±7.08	0.11	29.78	2.98±2.83	0.06	145.18	18.15±15.58	0.14
Total Shrub		**5363.16**	**297.95±51.59**	**3.5**	**2173.01**	**217.3±24.07**	**4.58**	**3190.15**	**398.77±104.87**	**3.01**
Mallotus nudiflorus (L.) Kulju & Welzen	**Tree**	**254.87**	**14.16±9.71**	**0.17**	**93.81**	**9.38±7.91**	**0.2**	**161.06**	**20.13±20.13**	**0.15**
Total Biomass		**153351.3**	**4381.47±2268.4**	**100**	**47408.77**	**1354.54±641.30**	**100**	**105942.5**	**3026.93±1632.65**	**100**

TB – Total available biomass in g m^{-2}, MB – Mean Biomass ± standard error in g m^{-2}, % – Percentage of available biomass.

Table 5.2. Seasonal differences in the forage biomass in Kaziranga National Park, Assam, India.

Season	Plant	Mann-Whitney (U)	p
Between dry and wet season	Forage Biomass	41766.5	**0.001**
	Grass	1525.5	**0.032**
	Sedge	103	0.063
	Herb	7099	**0.002**
	Climber	343.5	0.773
	Shrub	1643.5	0.115
	Tree	38	0.784

5.3.2 Forage Preference

Throughout the year, *Saccharum* spp. contributed the most to available and used forage of large herbivores (Figures 5.2 and 5.3). *L. salicifolia* was the most preferred forage of elephant (D=0.76), *M. micrantha* of rhino (D=0.70) and buffalo (D=0.66), *F. lineata* of hog deer (D=0.69), *P. conjugatum* of swamp deer (D=0.53), and *A. nigra* of sambar (D=0.46) (Figure 5.4 and Appendix 16-21). *M. umbellata* was completely avoided (D=-1) by rhino, elephant, buffalo, swamp deer and sambar, and avoided by hog deer (D=-0.97). *Mimosa* spp. was completely avoided (D=-1) by the meso-herbivores, and avoided by buffalo (D=-0.77), elephant (D=-0.75) and rhino (D=-0.33).

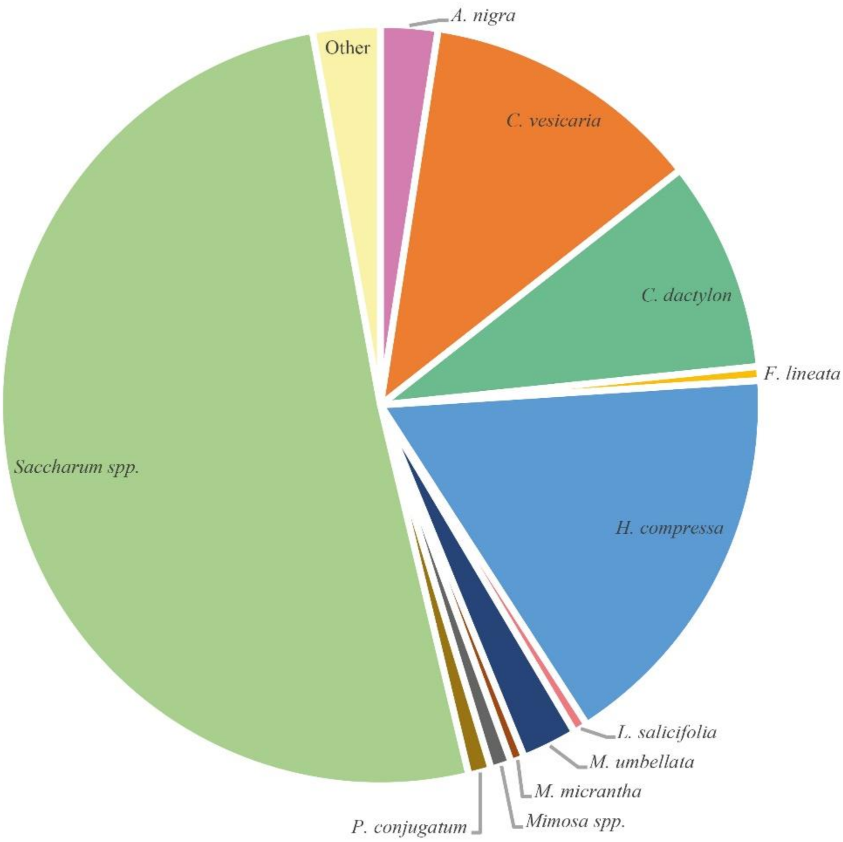


Figure 5.2. Availability of plants contributing more than 1% to the forage biomass throughout the year.

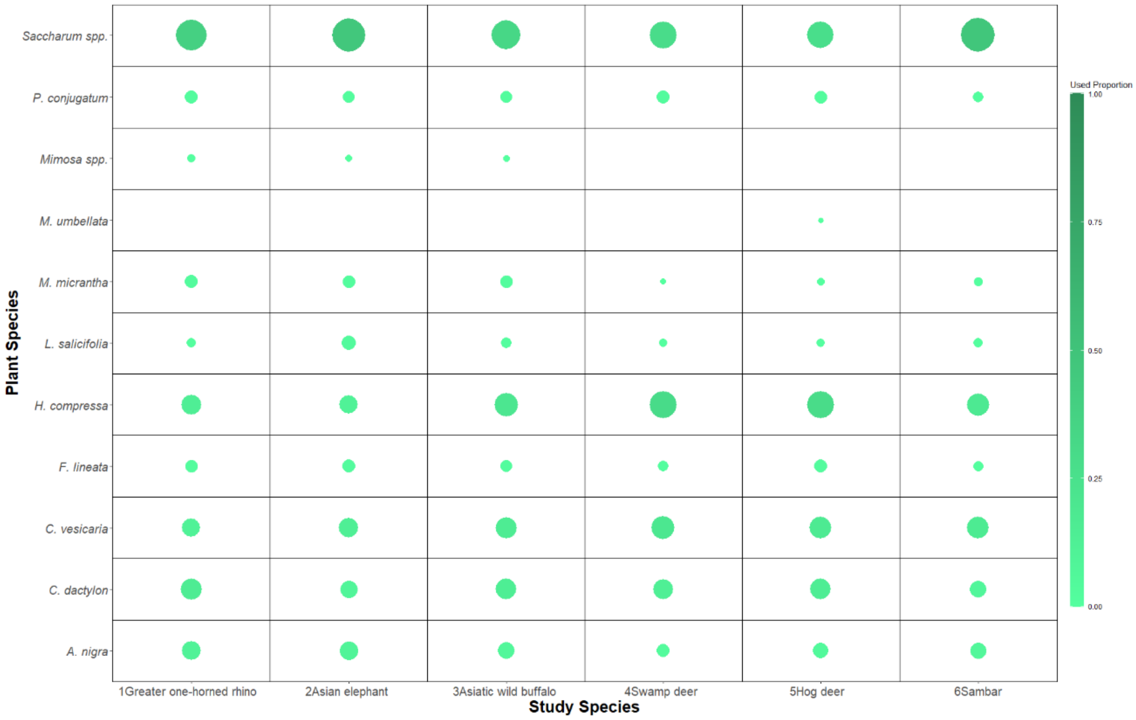


Figure 5.3. Utilization of plants contributing more than 1% to the forage biomass throughout the year.

Figure 5.4. Selectivity of plants contributing more than 1% to the forage biomass throughout the year.

In the dry season, *Saccharum* spp. contributed the most to available and used forage of large herbivores (Figures 5.5 and 5.6). *L. salicifolia* was the most preferred forage of elephant (D=0.76), *A. nigra* of rhino (D=0.61) and sambar (D=0.36), *F. lineata* of hog deer (D=0.59) and buffalo (D=0.56), and *P. conjugatum* of swamp deer (D=0.44) (Figure 5.7 and Appendix 16-21). *M. umbellata* was completely avoided (D=-1) by rhino, elephant, buffalo, swamp deer and sambar, and avoided by hog deer (D=-0.96). Similarly, *Mimosa* spp. was completely avoided (D=-1) by swamp deer, hog deer and sambar, and avoided by buffalo (D=-0.82), elephant (D=-0.67) and rhino (D=-0.56). Although preferred by rhino (D=0.61), elephant (D=0.55) and buffalo (D=0.49), *M. micrantha* was completely avoided (D=-1) by swamp deer, and avoided by hog deer (D=-0.53) and sambar (D=-0.19).

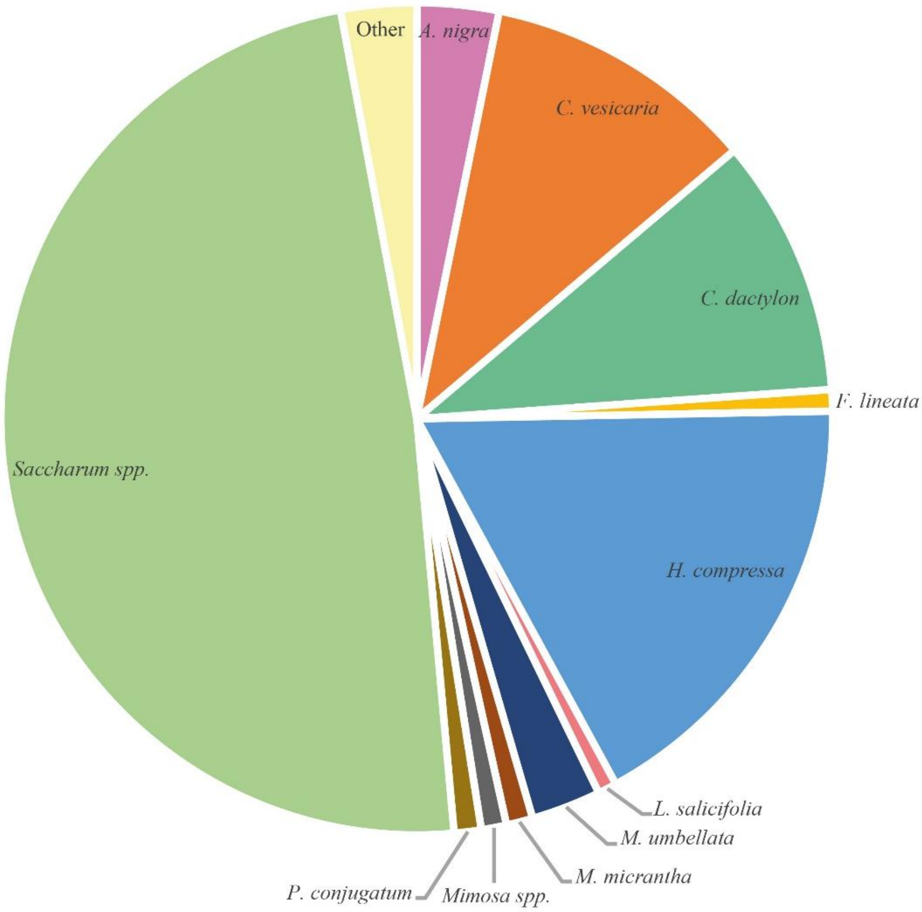


Figure 5.5. Availability of plants contributing more than 1% to the forage biomass in the dry season.

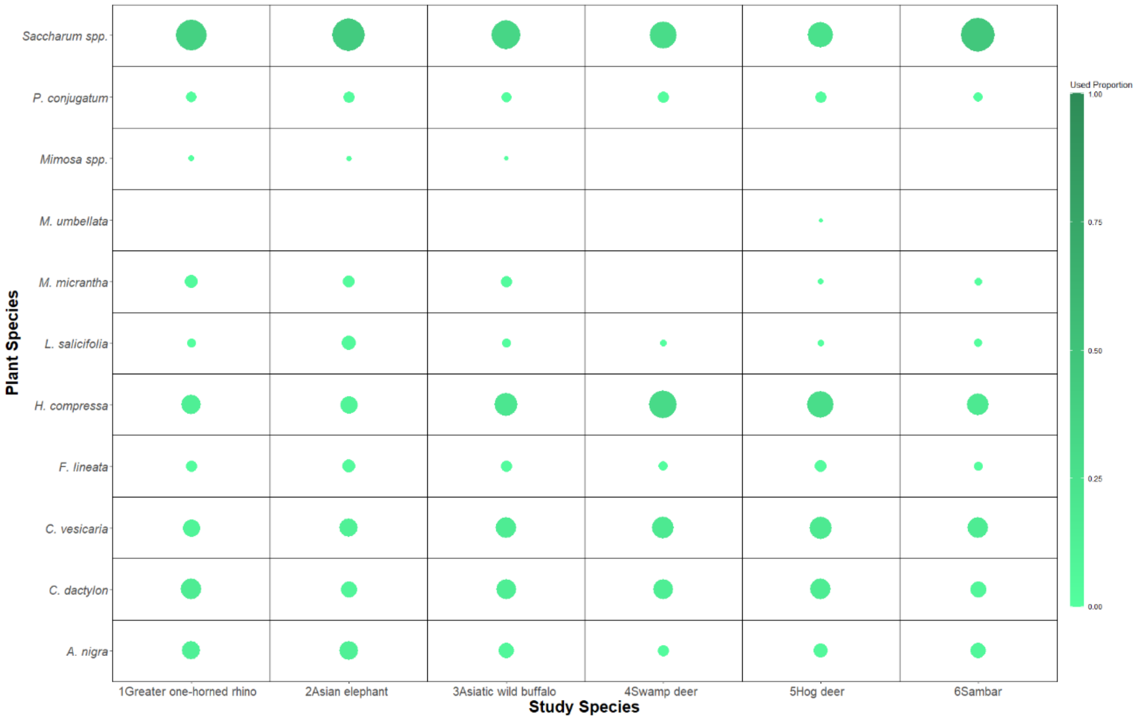


Figure 5.6. Utilization of plants contributing more than 1% to the forage biomass in the dry season.

Figure 5.7. Selectivity of plants contributing more than 1% to the forage biomass in the dry season.

In the wet season, *Saccharum* spp. contributed the most to available and used forage of large herbivores (Figures 5.8 and 5.9). *P. conjugatum* was the most preferred forage of rhino (D=0.57), buffalo (D=0.42) and swamp deer (D=0.59), *C. vesicaria* of sambar (D=0.51), *L. salicifolia* of elephant (D=0.43), and *F. lineata* of hog deer (D=0.36). *M. umbellata* was completely avoided by both mega- and meso-herbivores (Figure 5.10 and Appendix 16-21). *Mimosa* spp. was completely avoided (D=-1) by elephant, swamp deer, hog deer and sambar, and avoided by buffalo (D=-0.74) and rhino (D=-0.21).

Throughout the study year and in the dry season, the most consumed and available tall grass, *Saccharum* spp. was avoided by both mega and meso-herbivores. It was preferred by elephant (D=0.19) and sambar (D=0.16) only in the wet season.

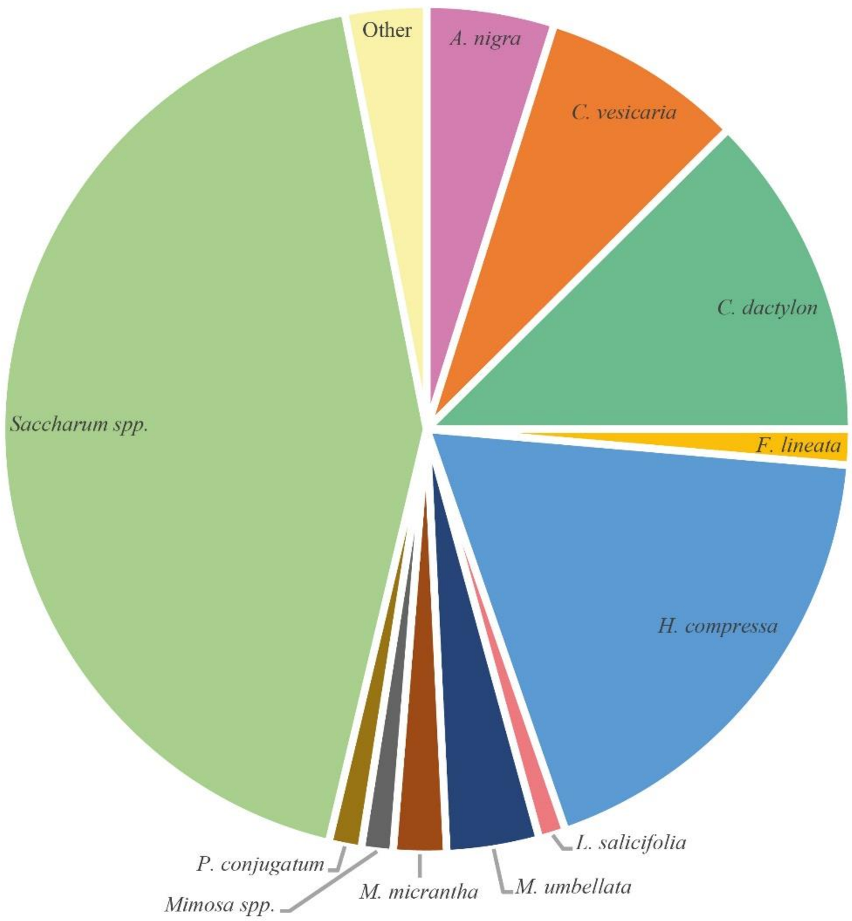


Figure 5.8. Availability of plants contributing more than 1% to the forage biomass in the wet season.

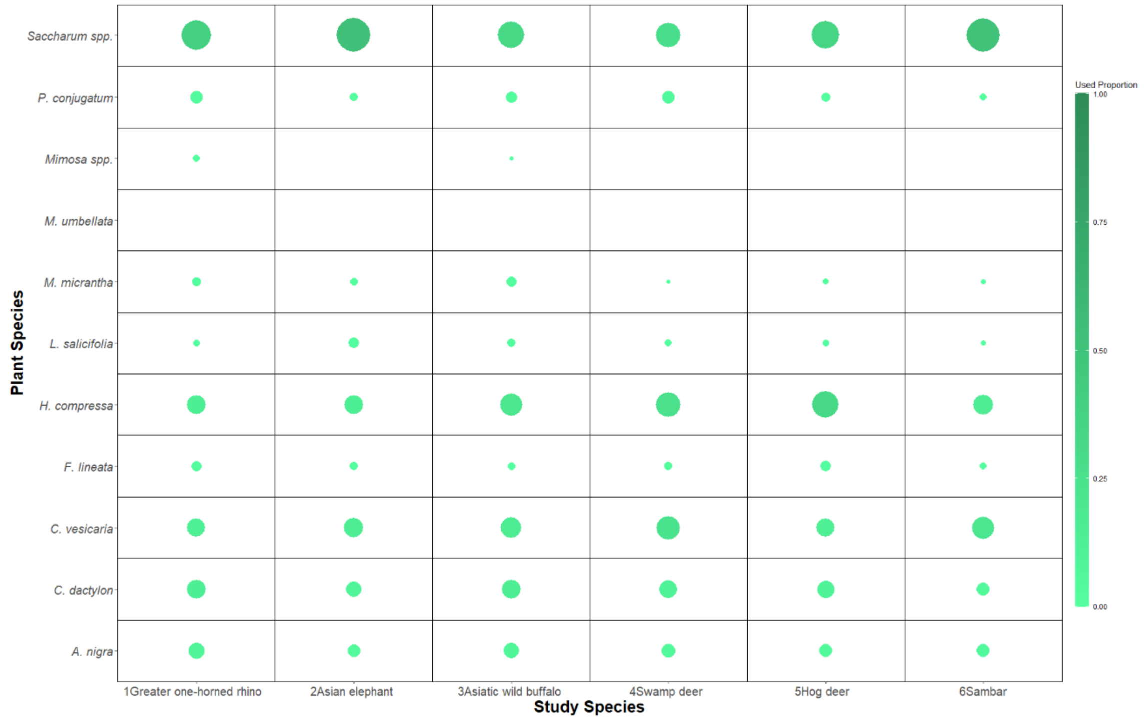


Figure 5.9. Utilization of plants contributing more than 1% to the forage biomass in the wet season.

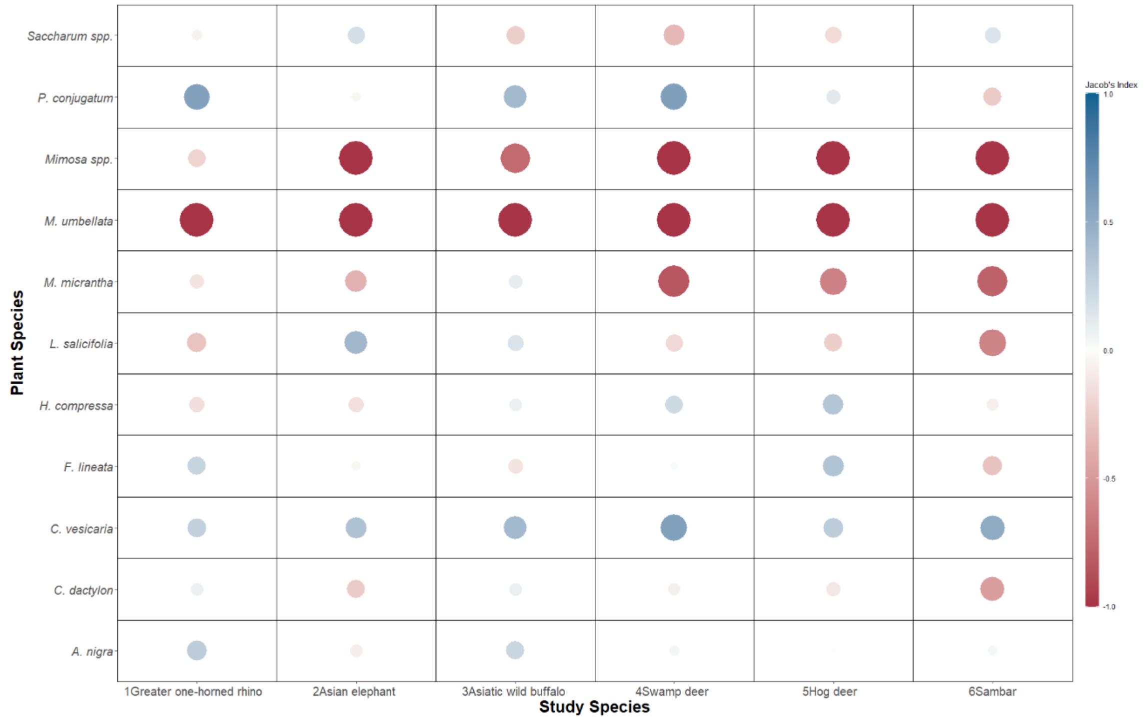


Figure 5.10. Selectivity of plants contributing more than 1% to the forage biomass in the wet season.

5.3.3 Dietary Similarities and Dissimilarities Within and Among Guilds

Throughout the year, among SLH, NMDS ordination plots illustrated the highest dietary similarities among buffalo, swamp deer and hog deer, and high dissimilarities among elephant and swamp deer (Figure 5.11). Among SLH, permANOVA test indicated that their diet differed significantly with an overlap of forage species consumed by other study species with similar feeding strategies (adonis pseudo $F_{1,975}$=39.53, df=5, R^2=0.091, P≤0.001). Among mega-herbivores, NMDS plots illustrated the highest dietary similarities between rhino and buffalo, and high dissimilarities between elephant and buffalo (Figure 5.12). Among meso-herbivores, NMDS plots illustrated the highest dietary similarities between swamp deer and hog deer, and high dissimilarities between swamp deer and sambar (Figure 5.13). The permANOVA also elucidates within guild niche segregation among mega-herbivores (adonis pseudo $F_{1,025}$=39.51, df=2, R^2=0.071, P≤0.001) and meso-herbivores (adonis pseudo F_{950}=29.72, df=2, R^2=0.05, P≤0.001). This also indicates that the diet differed significantly within both guilds of mega- and meso-herbivores, with the overlap of forage species consumed by other study species with similar feeding strategies.

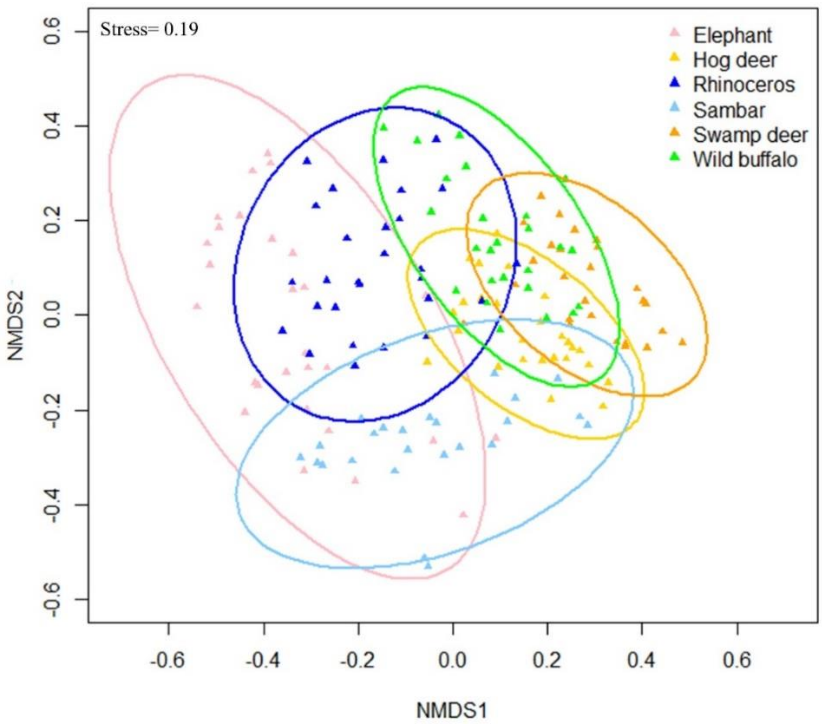


Figure 5.11. NMDS graph depicting the diet partitioning among SLH based on Bray-Curtis dissimilarity (adonis pseudo $F_{1,\ 975}$ = 39.54, df = 5, R^2 = 0.91, P ≤ 0.001).

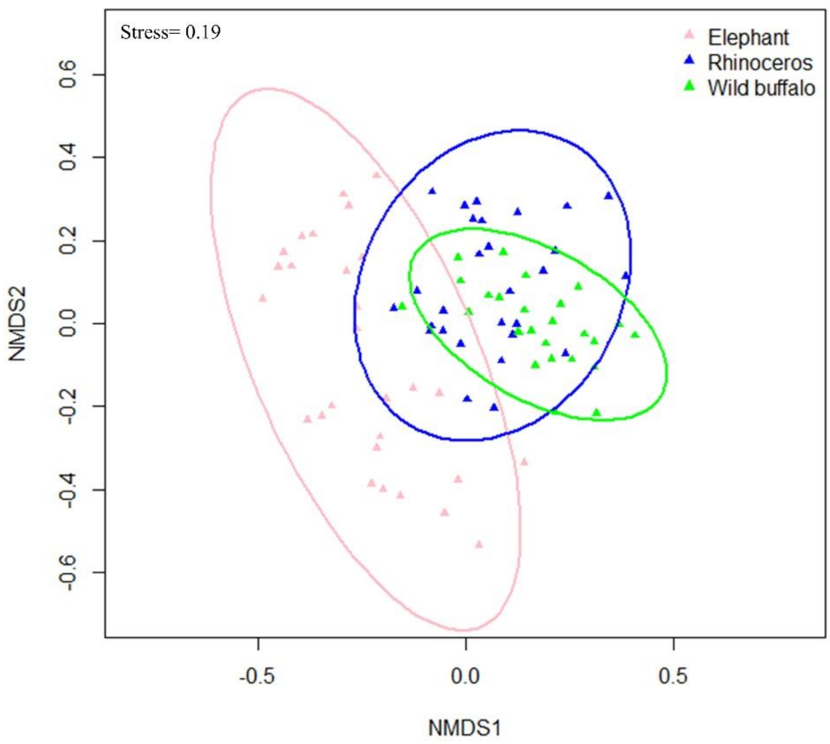


Figure 5.12. NMDS graph depicting diet partitioning among mega-herbivores based on Bray-Curtis dissimilarity (adonis pseudo $F_{1,025}$ = 39.51, df = 2, R^2 = 0.071, P ≤ 0.001).

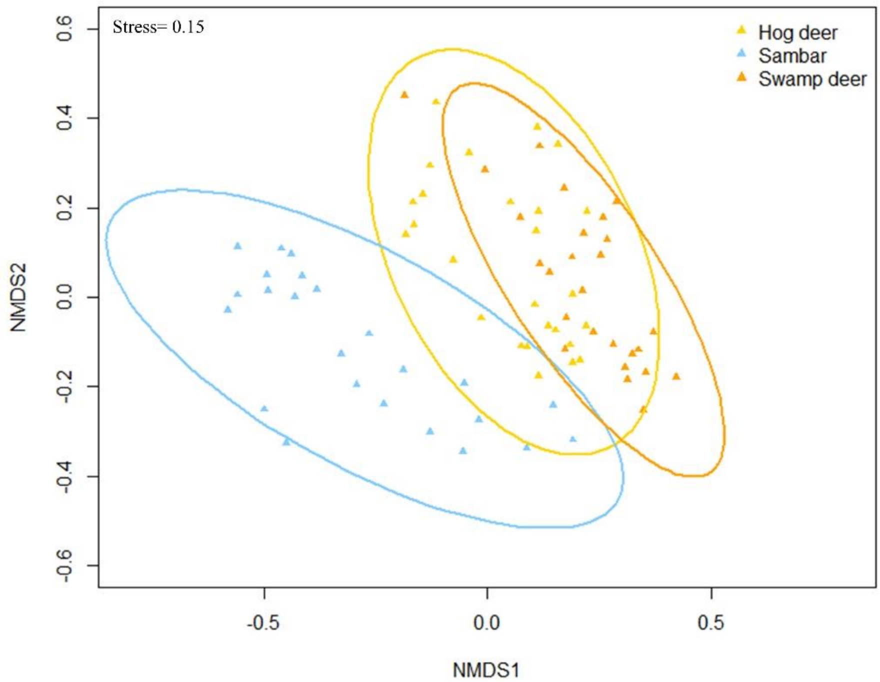


Figure 5.13. NMDS graph depicting diet partitioning among meso-herbivores based on Bray-Curtis dissimilarity (adonis pseudo F_{950} = 29.72, df = 2, R^2 = 0.05, P ≤ 0.001).

Among SLH, biologically significant diet overlap was recorded throughout the year (SI=0.76, ANOSIM R=0.19, p=0.001), in the dry season (SI=0.74, ANOSIM R=0.23, p=0.001), and the wet season (SI=0.74, ANOSIM R=0.19, p=0.001). Among SLH, SIMPER revealed average dissimilarity (AD) of 23.89% throughout the year, 25.71% in the dry season and 25.90% in the wet season. Throughout the year, top forage species like *H. compressa* (AD=1.99%), *Calamus tenuis* (AD=1.34%) and *Saccharum* spp. (AD=1.32%) significantly explain the differences in the diet among SLH. Similarly, in the dry season, *H. compressa* (AD=2.25%), *C. tenuis* (AD=1.55%) and *Saccharum* spp. (AD=1.08%) significantly explain the differences in the diet among SLH, and *Saccharum* spp. (AD=3.01%), *H. compressa* (AD=1.74%) and *I. cylindrica* (AD=0.91%) in the wet season.

Throughout the year, and in the dry and wet seasons, pairwise maximum biologically significant diet overlap was recorded between swamp deer and hog deer (SI=0.86, ANOSIM R=0.08, p=0.001), buffalo and hog deer (SI=0.84, ANOSIM R=0.08, p=0.001), and rhino and buffalo (SI=0.80, ANOSIM R=0.08, p=0.001), respectively. The maximum diet dissimilarity was recorded between elephant and swamp deer throughout the year (SI=0.64, ANOSIM R=0.37, p=0.001), in the dry season (SI=0.70, ANOSIM R=0.47, p=0.001), and the wet season (SI=0.63, ANOSIM R=0.37, p=0.001). SIMPER revealed pairwise maximum average dissimilarity between elephant and swamp deer throughout the year (AD=36.18%), in the dry season (AD=37.47%), and the wet season (AD=36.46%). Throughout the year, top forage species like *C. tenuis* (AD=3.98%), *H. compressa* (AD=3.79%), and *Saccharum* spp. (AD=2.46%) significantly explained the differences in elephant and swamp deer diet (Table 5.3). In the dry season, *H. compressa* (AD=4.68%), *C. tenuis* (AD=4.66%) and *Dillenia indica* (AD=1.99%) significantly explained the differences in elephant and swamp deer diet (Table 5.4). In the wet season, *Saccharum* spp. (AD=6.46%), *Mallotus nudiflorus* (AD=2.40%) and *C. tenuis* (AD=2.30%) significantly explained the differences in elephant and swamp deer diets (Table 5.5).

Table 5.3. Pairwise dietary similarities (Schoener's Index & R ANOSIM) and dissimilarities (SIMPER) among large herbivores throughout the year.

Group	SI	R ANOSIM	SIMPER				
			Av.diss	**Forage Species**	**Av.diss**	**Cont%**	**Cum%**
Ele_HD	0.68	0.35	32.19	*Calamus tenuis*	4.00	12.42	12.42
				Hemarthria compressa	3.82	11.85	24.27
				Saccharum spp.	2.62	8.15	32.42
Ele_Rhi	0.76	0.21	23.95	*Calamus tenuis*	3.91	16.31	16.31
				Cynodon dactylon	1.46	6.09	22.40
				Amaranthus spinosus	1.09	4.56	26.95
Ele_Sam	0.75	0.20	24.70	*Calamus tenuis*	3.95	16.01	16.01
				Mallotus nudiflorus	1.13	4.59	20.60
				Solanum americanum	1.08	4.36	24.96
Ele_SD	**0.64**	**0.39**	**36.18**	*Calamus tenuis*	3.98	10.99	10.99
				Hemarthria compressa	3.79	10.48	21.46
				Saccharum spp.	2.46	6.79	28.26
Ele_WB	0.73	0.27	27.21	*Calamus tenuis*	3.99	14.65	14.65
				Hemarthria compressa	2.33	8.56	23.21
				Echinochloa crus-galli	1.89	6.96	30.17
HD_Rhi	0.74	0.21	25.94	*Hemarthria compressa*	3.17	12.23	12.23
				Saccharum spp.	1.84	7.10	19.33
				Carex vesicaria	1.45	5.60	24.93
HD_Sam	0.77	0.16	22.85	*Hemarthria compressa*	2.83	12.38	12.38
				Saccharum spp.	2.30	10.05	22.42
				Cynodon dactylon	1.70	7.44	29.87
HD_SD	**0.86**	0.08	**14.03**	*Imperata cylindrica*	1.92	13.69	13.69
				Tetrastigma dubium	0.81	5.81	19.49
				Kyllinga brevifolia	0.68	4.86	24.36
HD_WB	0.86	**0.06**	14.29	*Saccharum spp.*	1.54	10.80	10.80
				Hemarthria compressa	1.49	10.45	21.24
				Ziziphus jujuba	0.81	5.70	26.94
Rhi_Sam	0.78	0.14	22.45	*Ziziphus jujuba*	1.79	7.96	7.96
				Cynodon dactylon	1.68	7.47	15.44
				Amaranthus spinosus	1.12	5.01	20.44
Rhi_SD	0.71	0.24	29.12	*Hemarthria compressa*	3.15	10.82	10.82
				Imperata cylindrica	1.86	6.40	17.22
				Carex vesicaria	1.84	6.31	23.53
Rhi_WB	0.83	0.10	16.93	*Hemarthria compressa*	1.69	9.96	9.96
				Carex vesicaria	1.38	8.12	18.08
				Amaranthus spinosus	1.09	6.43	24.50
Sam_SD	0.72	0.23	28.26	*Hemarthria compressa*	2.81	9.94	9.94
				Saccharum spp.	2.13	7.54	17.48
				Imperata cylindrica	1.71	6.04	23.52
Sam_WB	0.78	0.15	22.50	*Cynodon dactylon*	1.80	7.99	7.99
				Ziziphus jujuba	1.58	7.01	15.00
				Hemarthria compressa	1.34	5.97	20.96
SD_WB	0.82	0.10	17.73	*Imperata cylindrica*	1.65	9.30	9.30
				Hemarthria compressa	1.48	8.35	17.64
				Saccharum spp.	1.38	7.79	25.43

Rhi- Greater one-horned rhino, Ele- Asian Elephant, WB- Asiatic Wild Buffalo, SD- Swamp Deer, HD- Hog Deer, Sam- Sambar, SI- Schoener index, Av.diss- Average dissimilarity, Cont%- contribution percentage, Cum%- cumulative %. The values in bold indicate the highest overlap.

Table 5.4. Pairwise dietary similarities (Schoener's Index & R ANOSIM) and dissimilarities (SIMPER) among large herbivores in the dry season.

Group	SI	R ANOSIM	SIMPER				
			Av.diss	Forage Species	Av.diss	Cont%	Cum%
Ele-HD	0.65	0.44	35.33	*Calamus tenuis*	4.68	13.24	13.24
				Hemarthria compressa	3.93	11.13	24.38
				Echinochloa crus-galli	2.06	5.84	30.22
Ele-Rhi	0.74	0.27	26.38	*Calamus tenuis*	4.63	17.56	17.56
				Cynodon dactylon	1.60	6.06	23.61
				Ziziphus jujuba	1.26	4.78	28.39
Ele-Sam	0.72	0.26	27.61	*Calamus tenuis*	4.63	16.76	16.76
				Hemarthria compressa	1.38	4.99	21.75
				Solanum americanum	1.09	3.95	25.71
Ele-SD	0.63	0.47	37.47	*Hemarthria compressa*	4.68	12.50	12.50
				Calamus tenuis	4.66	12.44	24.93
				Dillenia indica	1.99	5.32	30.25
Ele-WB	0.71	0.33	28.92	*Calamus tenuis*	4.67	16.13	16.13
				Hemarthria compressa	2.83	9.77	25.90
				Echinochloa crus-galli	1.95	6.76	32.66
HD-Rhi	0.70	0.28	29.58	*Hemarthria compressa*	2.93	9.90	9.90
				Saccharum spp.	2.20	7.45	17.35
				Carex vesicaria	1.81	6.13	23.48
HD-Sam	0.76	0.18	24.28	*Hemarthria compressa*	2.55	10.48	10.48
				Saccharum spp.	2.44	10.04	20.52
				Cynodon dactylon	1.82	7.50	28.02
HD-SD	0.84	0.08	15.67	*Imperata cylindrica*	1.77	11.30	11.30
				Saccharum spp.	1.13	7.23	18.53
				Ziziphus jujuba	0.88	5.60	24.14
HD-WB	0.84	0.08	15.52	*Saccharum spp.*	2.40	15.44	15.44
				Hemarthria compressa	1.11	7.16	22.61
				Ziziphus jujuba	0.97	6.22	28.83
Rhi-Sam	0.75	0.17	25.10	*Ziziphus jujuba*	2.32	9.24	9.24
				Cynodon dactylon	1.65	6.59	15.83
				Amaranthus spinosus	1.24	4.96	20.79
Rhi-SD	0.70	0.28	30.11	*Hemarthria compressa*	3.68	12.23	12.23
				Carex vesicaria	1.98	6.59	18.82
				Imperata cylindrica	1.71	5.69	24.51
Rhi-WB	0.80	0.14	19.84	*Hemarthria compressa*	1.82	9.17	9.17
				Carex vesicaria	1.63	8.19	17.36
				Amaranthus spinosus	1.23	6.21	23.58
Sam-SD	0.71	0.23	28.99	*Hemarthria compressa*	3.30	11.39	11.39
				Ziziphus jujuba	1.63	5.63	17.02
				Cynodon dactylon	1.63	5.61	22.63
Sam-WB	0.77	0.15	22.94	*Cynodon dactylon*	1.79	7.79	7.79

Group	SI	R ANOSIM	SIMPER				
			Av.diss	Forage Species	Av.diss	Cont%	Cum%
				Ziziphus jujuba	1.72	7.49	15.28
				Hemarthria compressa	1.44	6.27	21.55
SD-WB	0.82	0.10	17.91	*Hemarthria compressa*	1.88	10.50	10.50
				Imperata cylindrica	1.42	7.92	18.42
				Kyllinga brevifolia	1.29	7.18	25.60

Rhi- Greater one-horned rhino, Ele- Asian Elephant, WB- Asiatic Wild Buffalo, SD- Swamp Deer, HD- Hog Deer, Sam- Sambar, SI- Schoener index, Av.diss- Average dissimilarity, Cont%- contribution percentage, Cum%- cumulative %. The values in bold indicate the highest overlap.

Table 5.5. Pairwise dietary similarities (Schoener's Index & R ANOSIM) and dissimilarities (SIMPER) among large herbivores in the wet season.

Group	SI	R ANOSIM	SIMPER				
			Av.diss	Forage Species	Av.diss	Cont%	Cum%
Ele-HD	0.71	0.23	29.49	*Hemarthria compressa*	3.94	13.37	13.37
				Saccharum spp.	3.36	11.40	24.77
				Mallotus nudiflorus	2.44	8.26	33.03
Ele-Rhi	0.74	0.18	25.74	*Saccharum spp.*	3.23	12.53	12.53
				Mallotus nudiflorus	2.21	8.59	21.12
				Calamus tenuis	2.13	8.25	29.37
Ele-Sam	0.77	0.14	22.97	*Calamus tenuis*	2.30	10.02	10.02
				Mallotus nudiflorus	2.30	10.00	20.02
				Echinochloa crus-galli	1.20	5.24	25.26
Ele-SD	0.63	0.37	36.46	*Saccharum spp.*	6.46	17.73	17.73
				Mallotus nudiflorus	2.40	6.58	24.31
				Calamus tenuis	2.30	6.30	30.61
Ele-WB	0.67	0.28	32.80	*Saccharum spp.*	4.84	14.75	14.75
				Calamus tenuis	2.31	7.05	21.80
				Mallotus nudiflorus	2.27	6.90	28.70
HD-Rhi	0.79	0.12	21.00	*Hemarthria compressa*	4.22	20.11	20.11
				Amaranthus spinosus	1.17	5.57	25.67
				Ageratum conyzoides	0.90	4.29	29.96
HD-Sam	0.76	0.15	24.36	*Hemarthria compressa*	3.70	15.20	15.20
				Saccharum spp.	2.71	11.11	26.31
				Cynodon dactylon	1.31	5.38	31.69
HD-SD	0.75	0.21	25.43	*Saccharum spp.*	3.19	12.52	12.52
				Hemarthria compressa	2.55	10.02	22.55
				Imperata cylindrica	2.32	9.11	31.66
HD-WB	0.79	0.12	20.91	*Hemarthria compressa*	2.87	13.72	13.72
				Saccharum spp.	1.51	7.24	20.96
				Hypericum sp.	1.04	4.96	25.92
Rhi-Sam	0.75	0.09	24.53	*Saccharum spp.*	2.58	10.50	10.50
				Cynodon dactylon	1.82	7.42	17.92
				Carex vesicaria	1.69	6.88	24.79
Rhi-SD	0.69	0.23	31.05	*Saccharum spp.*	3.25	10.47	10.47
				Imperata cylindrica	2.36	7.60	18.07
				Hemarthria compressa	1.66	5.33	23.41
Rhi-WB	0.80	0.08	20.25	*Saccharum spp.*	1.60	7.89	7.89

Group	SI	R ANOSIM	SIMPER				
			Av.diss	Forage Species	Av.diss	Cont%	Cum%
				Hemarthria compressa	1.37	6.74	14.64
				Kyllinga brevifolia	1.06	5.25	19.88
Sam-SD	0.73	0.26	26.95	*Saccharum spp.*	5.83	21.63	21.63
				Imperata cylindrica	1.77	6.56	28.19
				Hemarthria compressa	1.14	4.23	32.42
Sam-WB	0.74	0.16	25.56	*Saccharum spp.*	4.19	16.40	16.40
				Cynodon dactylon	1.89	7.39	23.79
				Eleocharis acutangula	1.25	4.88	28.66
SD-WB	0.79	0.15	20.98	*Imperata cylindrica*	2.33	11.10	11.10
				Saccharum spp.	1.67	7.97	19.07
				Eleocharis acutangula	1.38	6.57	25.64

Rhi- Greater one-horned rhino, Ele- Asian Elephant, WB- Asiatic Wild Buffalo, SD- Swamp Deer, HD- Hog Deer, Sam- Sambar, SI- Schoener index, Av.diss- Average dissimilarity, Cont%- contribution percentage, Cum%- cumulative %. The values in bold indicate the highest overlap.

5.4 Discussion

This study recorded a significant increase in available forage biomass from the dry to the wet season, probably due to precipitation, reproductive alluvial soil and controlled burning (during the dry season) (Vasu & Singh, 2015). Grasses contributed the most to the available forage biomass compared to other growth forms. Based on forage availability, both mega- and meso-herbivores switch their most preferred forage from browse to graze species, and vice versa, which indicates that seasonal availability of forage influences the forage selectivity of mega- and meso-herbivores. Irrespective of season, dicot was the most preferred forage of elephant (*L. salicifolia*), whereas monocots were the most preferred forage of swamp deer (*P. conjugatum*) and sambar (*A. nigra* & *C. vesicaria*). From dry to wet season, rhino, buffalo and hog deer shift their most preferred forage from dicot to monocot, possibly due to a significant increase in the availability and nutrient quality of grasses from the dry to the wet season, large herbivores switched their preferred forage from browse to graze species (Devi et al., 2022a). Compared to monocot plants, dicots have high soluble cell concentration and nitrogen content, which might benefit large herbivores, however they also have high lignin and secondary metabolites, which might be disadvantageous for large herbivores as it requires a lot of energy to detoxify (Ahrestani et al., 2016; Devi et al., 2022a). This might be responsible for the higher consumption and preference for monocots by large herbivores. Despite contributing most to the available and utilized forage biomass of

SLH, *Saccharum* spp. was avoided by SLH except by elephant and sambar in the wet season, which might be because both elephant and sambar switched their diet from browse to graze in the wet season primarily due to high availability, palatability and nutritional quality of *Saccharum* spp. in the wet season (Devi et al., 2022a).

Irrespective of season, the invasive *Mimosa* spp. was completely avoided by meso-herbivores and avoided by mega-herbivores. The high availability of *Mimosa* spp. throughout the year might be one of the reasons that mega-herbivores were feeding on the invasive. Guyton et al. (2020) conducted a study in Gorongosa National Park, Mozambique, and reported that possibly due to the nutrient quality of *Mimosa* spp., both mega and meso-herbivores browsed heavily on it. Throughout the year, and in the dry and wet seasons, mega- and meso-herbivores were almost avoiding *M. micrantha* by utilizing it less than its availability. It was completely avoided by the swamp deer in the dry season. One of the reasons for its consumption might be its entanglement with the principal forage *Saccharum* spp. and other forage grass species (Ram, 2008). Another invasive climber *M. umbellata* was completely avoided by mega- and meso-herbivores throughout the year, and in both seasons, except for hog deer, who avoided this invasive by utilizing it significantly less than its availability. The results from forage availability indicate that the high availability of the aforementioned invasive species, irrespective of season, might be a reason for their consumption by both mega- and meso-herbivores. Hence, the expansion of invasives can limit resources available to large herbivores and possibly alter the feeding ecology of mega- and meso-herbivores in the areas they invade (Bhatt et al. 1994, Murali & Shetty 2001, Raghubanshi et al. 2005, Ahrestani, 2009).

This study revealed a biologically significant dietary overlap among SLH species irrespective of season. Rhino showed the highest pairwise dietary similarities with buffalo irrespective of the season. Throughout the year and in the dry season, elephant showed the highest pairwise dietary similarities with rhino, buffalo with hog deer, and swamp deer with hog deer. In the wet season, elephant showed the highest pairwise dietary similarities with sambar, buffalo with rhino, and swamp deer with buffalo. Hog deer showed the highest pairwise dietary similarities with swamp deer throughout the year, and with buffalo in the dry and wet seasons. Sambar showed high pairwise dietary similarities with rhino throughout the year, and with buffalo and elephant in the dry and wet seasons, respectively. A high dietary overlap can be interpreted as competition when resources are limited and as resource segregation when resources are abundant (Gotelli & Graves 1996; Mysterud 2000). Similarly, for the present study, biologically significant dietary overlap can be interpreted as competition; however, the abundant forage and herbivores' good physical state (field observation) showed no evidence of limited forage resources, even towards the end of the dry season. This was supported by Banerjee (2001), which reported that despite the utilization of similar habitats, no competition was recorded among rhino, buffalo, swamp deer and hog deer in KNP. Primarily, based on the present study, the availability of forage, especially monocots and grasses, throughout the year can be considered as the reason for high dietary overlap, as it forms a major portion of the diet of SLH (Devi et al., 2022a). Secondarily, the high dietary overlap might be because large herbivores can reduce competition and facilitate other herbivores by utilizing different parts of the same forage species or segregating resources at spatial and temporal gradients (Bell, 1971; Pansu et al., 2019).

This study also revealed that irrespective of season, rhino, elephant and sambar showed highest pairwise dissimilarities with swamp deer, which was attributed to the differences in the consumption of short and tall grasses, and tree species. Swamp deer are obligatory grassland species that mostly use short grassland as a foraging ground; however, rhino, elephant and sambar utilize mixed habitats as forage ground, including tall grassland, short grassland and woodland, which may contribute to dietary differences (Banerjee, 2001). This study also revealed highest pairwise dissimilarities of buffalo, swamp deer and hog deer with elephant, which was majorly attributed to the shrub *C. tenuis*, short and tall grasses, and tree species. The use of short grassland as a foraging ground by swamp deer, both tall and short grassland by buffalo and mixed habitat by hog deer, may contribute to their dietary differences with elephant (Banerjee, 2001). Elephant, with their large body size and home range, have more opportunity to explore mixed habitats (woodland, tall and short grasslands) for forage, whereas buffalo, swamp deer and hog deer, with their smaller home range, have limited opportunity (Sukumar, 1990; Banerjee, 2001).

The results suggest that body size, resource availability and, possibly, habitat utilization and home ranges are responsible for dietary similarities and dissimilarities among SLH. In most parts of the world, rhinos and buffalo no longer coexist with elephants, swamp deer, hog deer and sambar (Pradhan et al., 2008). Therefore, little is known about the degree of determinants of inter- and intra-specific diet variation among these herbivores. This study quantifies dietary overlap at the taxonomic level, although many studies provide it in terms of growth forms, monocots (graze) and dicots (browse), or stable carbon isotopes, which makes it challenging to provide comparative quantification of diet from different studies as they are unlikely to be informative (Sankar, 1994; Pradhan et al., 2008; Ahrestani, 2009).

5.5 Conclusion

The present study provides insight into how coexisting sympatric wild large herbivores change their seasonal dietary overlap and forage selection with respect to forage availability. The findings of this study revealed that from the dry to wet season, probably due to precipitation, there is a significant increase in forage biomass. Forage availability contributes to the forage preference of herbivores. From the dry to wet season, mega-herbivores shift their most preferred forage from browse to graze, and meso-herbivores, especially swamp deer, showed more affinity toward grasses. Besides resource availability, this can be explained by gut physiology, mouth size and predator risk.

Irrespective of the season, the invasive shrub *Mimosa* spp. was totally avoided by meso-herbivores, whereas mega-herbivores were feeding on *Mimosa* spp. due to its high availability and, possibly, nutrient quality (Guyton et al., 2020). Irrespective of season, the invasive climber *M. umbellata* was avoided by SLH. Invasive climber *M. micrantha* was preferred by buffalo (irrespective of season), and by rhino and elephant overall and in the dry season. It was avoided by swamp deer and hog deer irrespective of season, and by sambar in both the dry and wet seasons. Reasons for its consumption might be its entanglement with the principal forage *Saccharum* spp. and other forage grass species, and its availability throughout the year (Ram, 2008). Based on this chapter, it can be concluded that the proliferation and growth of invasives like *Mimosa* spp., *M.*

micrantha and *M. umbellata*, have the potential to impact the foraging ecology of herbivores. Limited studies have studied the physiological impacts on large herbivores from foraging on invasives. Therefore, scientific studies on the management of herbivores and plant community dynamics in riverine alluvial grasslands are crucial for maintaining and enhancing grassland integrity and long-term management of herbivores.

The findings of this chapter also revealed that irrespective of the season, biologically significant dietary overlap (>0.6) was recorded among SLH, mega-herbivores and meso-herbivores. This is attributed to sufficient forage availability and possibly due to the differences in the foraging strategies and resource segregation at a spatio-temporal scale. Forage segregation, despite being challenging to interpret at the taxonomic level, influences niche partitioning among mega and meso-herbivores. With the world's largest global population of rhino and buffalo, and a significant population of elephant, swamp deer, hog deer and sambar, KNP is one of the key protected areas in Asia. This study's findings are significant as no other research has investigated inter- and intra-specific differences in the diet of SLH with respect to resource availability within the riverine alluvial grasslands of the Brahmaputra floodplains. The findings of this chapter could be useful for the long-term management of the habitat of Asia's largest large herbivores.

CHAPTER 6
NUTRIENT DYNAMICS OF MAJOR FORAGE CONSUMED BY SIX LARGE HERBIVORES

Summary

The riverine alluvial grasslands support the last remaining populations of the Greater one-horned rhino, Asiatic wild buffalo and eastern swamp deer. Kaziranga National Park (KNP) in the Brahmaputra floodplains of Assam, India, is among the last remaining habitats supporting the sympatrically occurring six large herbivores (SLH), namely Greater one-horned rhino, Asian elephant, Asiatic wild buffalo, swamp deer, hog deer and sambar. Scientific knowledge on the foraging ecology of SLH could be useful in formulating informed management policy. The study investigated the seasonal nutrient parameters of major forage plants consumed by SLH in KNP and the nutrient factors that govern forage utilization. The nutritional value of 17 major forage species consumed by SLH was examined. The samples were collected twice every month from November 2015 to May 2016, oven-dried and analyzed. For laboratory analysis, standard methods were used to estimate crude protein (CP), ash content (AC), fibre [neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL)], and minerals [Calcium (Ca), Phosphorous (P), Potassium (K), Sodium (Na) and Magnesium (Mg)]. Significant seasonal differences in AC, CP, ADL, Na, K and P content were recorded only for monocots. Between the dry and wet seasons, *Saccharum* spp. (monocot contributing >9% to SLH diet), showed significant differences in AC, CP, ADL and K concentrations, and *Ziziphus jujuba* (dicot contributing >4% to SLH diet) showed a significant difference only in ADL concentration. CP, ADL, NDF, Ca, Na and P concentrations varied significantly between monocots and dicots. In the dry season, the concentrations of CP, NDF, Ca, Na and P, and in the wet season, the concentrations of Ca and Na varied significantly between monocot and dicot. The results revealed that ADL concentration influenced forage use by SLH in the dry season, except elephants, whose forage use was influenced by NDF concentration. AC and ADL concentrations influenced the major forage use by SLH in the wet season. In conclusion, throughout the year and in both the dry and wet seasons, dicots with high CP and mineral concentrations were more nutritious than monocots; whereas in the wet

season, monocots were nutritious and highly digestible. This study provides insights into the nutritional requirement of SLH and will, consequently, aid in their conservation and management.

6.1 Introduction

In subtropical riverine alluvial grasslands, energy and nutrient intake by herbivores affect both their survival and reproduction (Ahrestani et al., 2012; Thapa et al., 2021). Thus, forage availability and quality are important factors as they limit the herbivores' population. Herbivores forage to fulfil their energy requirement, which is influenced by the nutrient concentration of forage, the amount of consumed forage, plant parts consumed, herbivores' body size and their digestive physiology (Van Soest, 1982; Gordon & Illius, 1996; van Langevelde et al., 2008; Thapa et al., 2021). Quality of forage is a function of the proportion between the cell constituents (generally carbohydrate, protein, ions and water) and the cell wall (structural components). The cell constituents can be digested directly through vertebrate enzymes or fermented rapidly through microbes, whereas the cell wall can be hydrolyzed slowly through bacterial and fungal enzymes (Demment & Van Soest, 1985; Banerjee, 2001). The high lignin content in the cell wall affects the digestion rate of the forage in herbivores (Van Soest, 1967; Banerjee, 2001). In other words, the quality of forage depends inversely on the lignin content and cell wall extent of the forage, indicating that digestible matter in a plant reduces with age and biomass (Van Soest, 1982; Thapa et al., 2021). Thus, the nutrient concentration and physico-chemical properties of a plant change with changes in the growth stage. For example, graminoids in their early growth stages are leafier (low proportion of the stem) and more digestible than older graminoids (Prins, 1996; Thapa et al., 2021). In such cases, gut physiology plays an important role in the digestion of coarse forage, which also affects the utilization and selection process of forage (Banerjee, 2001). Tolerance to low-quality forage depends on the body size and gut physiology of the herbivores (Gwynne & Bell, 1968; Bell, 1970; Bell, 1971; Tiwari, 2009). According to Bell–Jarman principle, larger-bodied herbivores are better equipped to satisfy their metabolic requirements on low-quality forage than smaller-bodied herbivores (Bell, 1971; Jarman, 1974).

Based on the dietary requirement, the mammalian herbivores have been classified into three major classes viz., concentrate, intermediate, and bulk and roughage feeders. Concentrate feeders are unable to tolerate large amounts of fibre in their diet and are thus limited to selective feeding on low fibre portions of plants. Intermediate feeders are adapted to either browsing or grazing, and can eat a wide variety of plants. This group shifts feeding behaviour according to the availability of forage and season, and is more versatile than concentrate selectors. Bulk and roughage feeders include, in decreasing order of their need for water, fresh grass eaters, roughage eaters and dry region grazers (Hofmann, 1973 & 1989; Janis & Erhardt, 1988).

Grzimek and Grzimek (1960) were the first to recognize that herbivores utilized neither all areas nor all grass species. In general, graminoids, especially when matured and senescent, have lower nutritive quality than browse (Wegge et al., 2006; Gwynne & Bell, 1968; Robbins, 2012). Nutrient concentration of the forage plant can be influenced by positive factors such as protein, carbohydrates, starch and minerals, and negative factors such as tannins and toxins, which reduce the forage digestibility (Freeland & Janzen, 1974; Westoby, 1978; Rosenthal & Janzen, 1979; Manjrekar, 2015). Chemical analysis of the forage utilized by herbivores is a helpful tool to reveal the uptake of nutrient content by herbivores, which is influenced by the protein content and digestibility of the forage plants and season (Putman, 1996). Seasonal changes in forage quality cause shifts in habitat use (Banerjee, 2001). Thus, forage quality is an important determinant of forage utilization and habitat use by herbivores (Schaller, 1967; Klein, 1970; Dinerstein, 1980; Banerjee, 2001). In view of this, the chapter aims to provide answers to the following research questions:

1) What is the seasonal nutrient content of major forage species consumed by SLH?
2) Is seasonal variation in the nutrient content responsible for the variation in the seasonal utilization of major forage species by SLH?

6.2 Methodology

6.2.1 Field Data Collection

Based on the results from the micro-histological analysis, the 17 forage plants consumed in the highest proportion by mega- and meso-herbivores viz., *Alpinia nigra*, *Calamus tenuis*, *Carex vesicaria*, *Cynodon dactylon*, *Echinochloa crus-galli*, *Hemarthria compressa*, *Imperata cylindrica*, *Saccharum* spp., *Ageratum conyzoides*, *Amaranthus viridis*, *Dillenia indica*, *Lippia alba*, *Litsea salicifolia*, *Mallotus nudiflorus*, *Oxalis corniculata*, *Solanum americanum* and *Ziziphus jujuba*, were collected twice every month from November 2015 to May 2016. These samples were then oven-dried at 60 ℃ for 48 hours in a hot air oven, packed in a labelled paper bag, and transported to the Wildlife Institute of India for their nutritional analysis. In the laboratory, the plant samples were dried at 50 ℃ in an oven for a week, finely grounded in a 1 mm mesh screen of Cyclotech's micro-Wiley mill (Tuboi & Hussain, 2016), and stored in airtight plastic bags. Standard methods were used to estimate crude protein, ash content, fibre (NDF, ADF and ADL), and mineral (Ca, P, Mg, K and Na) content.

6.2.2 Laboratory Analysis

6.2.2a Crude protein (CP)

Crude protein concentration was estimated using the Kjeldahl method, in which Auto Kjeldahl Nitrogen Analyzer (Foss Analytical 2003a) was used for the analysis (Maynard & Loosli 1969). The Auto Kjeldahl nitrogen analyzer consists of two separate units, the block digester and the distillation titration assembly. For digestion, 0.5 gm of the oven-dried sample was mixed with a catalyst (CuSO4 + K2SO4) and 10 ml of concentrated sulphuric acid. Then this mixture was digested in a digestion chamber at 420 ℃ for five to six hours in the block digester. The digested samples were transferred into the distillation titration assembly, where the ammonia generated during distillation was absorbed in 2% boric acid, which was then titrated against 0.01N sulphuric acid. A blank (without a sample) was run for each set of samples. The percent crude protein was calculated using the following formula (Chaturvedi and Sankar, 2006):

$$n(\%) = \frac{(S - B) \times N \times 1.407}{Sample\ Weight\ (gm)}$$

Where n(%) represents the percentage of Nitrogen, S represents the volume of acid used against the sample, B represents the volume of acid used against a blank, and N represents the normality of acid.

$$\text{Crude Protein (CP) \%} = n \times 6.25$$

6.2.2b Ash content (AC)

Percent of ash was estimated through the combustion process using a muffle furnace instrument. For analysis, 1 gm of the oven-dried sample was taken in pre-weighed crucibles, and the crucibles were then burned in a muffle furnace at 550 ℃ for three hours to burn the entire sample into ashes. The crucibles were then cooled in a desiccator and weighed again. The proportion of the residue left after the combustion of organic matter in the sample was the ash content recorded for respective samples (AOAC, 1990; Chaturvedi & Sankar, 2006).

6.2.2c Fibre content

Fibre content was estimated in terms of neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) using Van Soest detergent method (Goering & Van Soest 1970). The Fibre Analyzer (FOSS Analytical 2003b and 2003c) was used for fibre analysis. For NDF and ADF estimation, 0.5 gm of the oven-dried sample was boiled and refluxed with 100 ml of neutral detergent solution (NDS) or acid detergent solution (ADS) in the Fibre Analyzer. It was filtered through a pre-weighed crucible, washed with hot water, and then with acetone. The crucibles were kept in the oven overnight at 80 ℃, then cooled in a desiccator and weighed (AOAC, 1990; Chaturvedi & Sankar, 2006). The residue that remained insoluble in the hot NDS or ADS was the amount of NDF or ADF, the percentage of which was calculated using the following formula (Chaturvedi and Sankar, 2006):

$$Lignin(\%) = \frac{(W_3 - W_1)}{W_2} \times 100$$

Where W_1 represents the empty crucible weight, W_2 represents the sample weight, and W_3 represents the weight of the crucible after the extraction process. The crucibles used for ADF estimation were processed with 20 ml of 72% sulphuric acid and kept for three hours. Afterwards, the acid was filtered off, and the content in the crucibles was washed with boiling water. The crucibles were kept overnight in an oven at 80 ℃ and weighed. The crucibles were then burned in a muffle furnace at 550 ℃ for three hours to burn the entire sample into ashes. The crucibles were then cooled in a desiccator and weighed again. The ADL (percent lignin) content was calculated using the following formula (Chaturvedi and Sankar, 2006):

$$Lignin(\%) = \frac{(W_4 - W_5)}{W_2} \times 100$$

Where W_2 represents the sample weight at ADF initiation, W_4 represents the weight after lignin extraction (crucible weight and lignin weight), and W_5 represents the weight after ash (crucible weight and ash weight).

6.2.2d Minerals

Among minerals, five macronutrients viz., Calcium (Ca), Phosphorous (P), Potassium (K), Sodium (Na) and Magnesium (Mg) were estimated. The Di-acid digestion technique was used to analyze the minerals, in which 0.5 gm of dried and processed plant samples were weighed and mixed with nitric acid and perchloric acid (9ml: 4ml). The mixture was digested in the digestion chamber for about five to six hours, from 180 °C to 200 °C. After cooling down, the mixture was filtered in a volumetric flask with double distilled water up to a volume of 100 ml (Chaturvedi & Sankar, 2006). In Atomic Absorption Spectrophotometer (AAS), the Di-acid digested mixture was used to estimate its Ca and Mg content. Similarly, in the Systronics flame photometer (128), the Di-acid digested mixture was used to estimate its Na and K content. AAS and flame photometer were calibrated using standard solutions of the elements to be examined. In UV Visible Spectrophotometer (Varian's Carry-100), the Di-acid digested mixture was used to estimate its P content. For data analysis, the parts per million (ppm) readings recorded for mineral parameters were converted into percentages (Allen et al., 1974).

6.2.3 Data Analysis

The seasonal differences in the nutrient content of major monocot and dicot forage plants were analyzed using a non-parametric Mann-Whitney U-test in SPSS version 22. Data pertaining to nutrient factors and the use of major forage plants was standardized using the standardization method by Legendre and Legendre (1998), in which the variables were standardized within the range of 0 to 1 (Quinn & Keough, 2002).

$$\mathbf{Yi = Y_i/Y_{max}}$$

where Y_i is the i value of variable Y and Y_{max} is the maximum value of variable Y. The effect of nutrient factor (predictor) on the use of major forage plants (response) was modelled using a generalized linear model (GLM) and Pearson's correlation analysis. The combinations of nutrient parameters viz., AC, CP, ADF, ADL, NDF, Ca, Mg, Na, K and P, of major forage plants consumed by large herbivores were taken as potential predictors. The percentage contribution of major forage species in the diet of SLH viz., Greater one-horned rhino (Rhi), Asian elephant (Ele), Asiatic wild buffalo (WB), swamp deer (SD), hog deer (HD) and sambar (Sam) was taken as the response variables.

Prior to Pearson correlation and GLM, the data was analyzed for multi-collinearity, primarily to avoid high correlation among the variables that can limit the accuracy of parameters (Quinn & Keough, 2002). Any addition and removal of a variable can result in large changes in parameter calculations (Brauner, 1998). Therefore, predictor and response variables were subjected to a multi-collinearity test using variance inflation factors (VIF), where a high VIF (>10) value indicates strong collinearity. With a low VIF (<10), no multi-collinearity was recorded among the variables. (Brauner, 1998; Quinn & Keough, 2002; Kutner et al., 2005; Ullah & Aslam, 2018). The analysis was carried out in R Studio (R Development Core Team 2012) using the package "mctest" of version 1.2 (Ullah & Aslam, 2018).

Pearson correlation (r) was used to estimate linear relationship strength between the variables. The strength of a linear relationship ranges from -1 (strong negative correlation) to +1 (strong positive correlation) (Quinn & Keough, 2002). Analysis was performed in R Studio (R Development Core Team 2012), using package "Hmisc" of version 0.84 (Harrell & Harrell, 2019) and "corrplot" of version 0.84 (Wei et al., 2017). GLM was used to assess the nutrient factors influencing the seasonal forage use by SLH. Based on AICc statistics, only the best-fit models were selected. For GLM, R package "MuMin" version 1.43.17 was used (Barton & Barton, 2019).

6.3 Results

6.3.1 Nutrient Content: Monocots

Among the monocots, throughout the year, highest CP was recorded for *E. crus-galli* (12.16 %) and lowest for *Saccharum* spp. (6.02%). In the dry season, highest CP was recorded for *C. tenuis* (10.87%) and lowest for *Saccharum* spp. (4.75%), whereas in the wet season, highest CP was recorded for *E. crus-galli* (16.47 %) and lowest for *A. nigra* (9.11 %) (Table 6.1- Table 6.3). Throughout the year and in the dry season, highest AC was recorded for *E. crus-galli* (16.17% and 17.31%) and lowest for *C. tenuis* (8.02% and 8.32%). In the wet season, highest AC was recorded for *E. crus-galli* (13.32%) and lowest for *Saccharum* spp. (4.74%). Throughout the year and in both the dry and wet seasons, highest ADF was recorded for *Saccharum* spp. (60.52%, 61.46% and 58.16%, respectively) and lowest for *E. crus-galli* (40.66%, 41.93% and 37.50%, respectively). Throughout the year and in the dry season, highest ADL was recorded for *C. tenuis* (19.15% and 19.77%, respectively) and lowest for *C. dactylon* (9.59% and 10.52%, respectively). In the wet season, highest ADL was recorded for *C. tenuis* (17.61%) and lowest for *I. cylindrica* (7.13%). Throughout the year, highest NDF was recorded for *I. cylindrica* (75.34%) and lowest for *E. crus-galli* (60.62%). In the dry season, highest NDF was recorded for *Saccharum* spp. (76.15%) and lowest for *E. crus-galli* (61.88%), whereas in the wet season, highest NDF was recorded for *C. dactylon* (75.27%) and lowest for *E. crus-galli* (57.49%).

Throughout the year, highest calcium was recorded for *E. crus-galli* (1.22 %) and lowest for *C. tenuis* (0.64%). In the dry season, highest calcium was recorded for *C. vesicaria* (1.07%) and lowest for *Saccharum* spp. (0.63%), whereas in the wet season, highest calcium was recorded for *E. crus-galli* (2.07%) and lowest for *C. tenuis* (0.61%). Throughout the year and in both dry and wet seasons, highest magnesium was recorded for *H. compressa* (0.57%, 0.47%, and 0.83%, respectively) and lowest for *C. tenuis* (0.12%, 0.10%, and 0.17 %, respectively). Throughout the year and in the dry season, highest sodium was recorded for *H. compressa* (0.06% and 0.05%, respectively) and lowest for *C. tenuis* (0.03% and 0.03%, respectively). In the wet season, highest sodium was recorded for *E. crus-galli* (0.09%) and lowest for *I. cylindrica* (0.04%). Throughout the year, highest potassium was recorded for *A. nigra* (2.58%) and lowest for *Saccharum* spp. (0.89%). In the dry season, highest potassium was recorded for *A. nigra* (2.46%) and lowest for *I. cylindrica* (0.71%), whereas in the wet season, highest potassium was recorded for *H. compressa* (3.24%) and lowest for *Saccharum* spp. (1.11%). Throughout the year and in the wet season, highest phosphorous was recorded for *H. compressa* (0.20% and 0.28%, respectively) and lowest for *C. tenuis* (0.06% and 0.07%, respectively). In the dry season, highest phosphorous was recorded for *H. compressa* (0.17%) and lowest for *I. cylindrica* (0.04%).

Compared to the dry season, monocots showed a higher mean concentration of CP, Ca, Mg, Na, K and P, and a lower mean concentration of AC, ADL, ADF and NDF in the wet season. There were significant differences in AC, CP, ADL, Na, K and P content (Mann-Whitney, $p < 0.05$) in monocots, between the dry and wet seasons (Table 6.4). The most consumed monocot species in the diet of mega- and meso-herbivores viz., *Saccharum* spp., showed significant differences in AC, CP, ADL and K concentrations (Mann-Whitney, $p < 0.05$), between the dry and wet seasons. Similarly, another majorly consumed monocots, *H. compressa* showed significant seasonal differences in AC, CP, ADL, Mg and K concentrations (Mann-Whitney, $p < 0.05$). Between the dry and wet seasons, *A. nigra*, *C. vesicaria*, *C. dactylon*, *E. crus-galli* and *I. cylindrica* also showed a significant difference in CP concentration (Mann-Whitney, $p < 0.05$).

6.3.2 Nutrient Content: Dicots

Among the dicots, throughout the year and in both the dry and wet seasons, highest CP concentration was recorded for *A. viridis* (17.88%, 17.40%, and 19.09, respectively) and lowest for *D. indica* (6.94%, 6.80%, and 7.26%, respectively) (Table 6.1- Table 6.3). Throughout the year and in the dry season, highest AC was recorded for *A. viridis* (19.31% and 18.84%, respectively) and lowest for *L. salicifolia* (5.49% and 5.20%, respectively). In the wet season, highest AC was recorded for *A. viridis* (20.49%) and lowest for *Z. jujuba* (5.88%). Throughout the year and in both the dry and wet seasons, highest ADF concentration was recorded for *L. salicifolia* (66.65%, 66.44%, and 67.16%, respectively) and lowest for *A. viridis* (35.33%, 35.75%, and 34.28%, respectively). Throughout the year, highest ADL was recorded for *O. corniculata* (17.11%) and lowest for *S. americanum* (13.44%). In the dry season, highest ADL was recorded for *O. corniculata* (17.44%) and lowest for *L. salicifolia* (13.91%), whereas in the wet season, highest ADL was recorded for *O. corniculata* (16.29%) and lowest for *Z. jujuba* (11.52%). Throughout the year and in both the dry and wet seasons, highest NDF concentration was recorded for *L. salicifolia* (72.42%, 72.10%, and 73.23%, respectively) and lowest for *A. viridis* (49.81%, 49.66%, and 50.17%, respectively).

Throughout the year and in the wet season, highest calcium was recorded for *A. viridis* (2.0% and 2.30%, respectively) and lowest for *L. salicifolia* (1.24% and 1.01%, respectively). In the dry season, highest calcium was recorded for *L. alba* (2.04%) and lowest for *O. corniculata* (1.30%). Throughout the year and in the dry season, highest magnesium was recorded for *A. viridis* (1.08% and 0.95%, respectively) and lowest for *L. salicifolia* (0.21% and 0.20%, respectively). In the wet season, highest magnesium was recorded for *A. viridis* (1.40%) and lowest for *Z. jujuba* (0.21%). Throughout the year and in both the dry and wet seasons, highest sodium concentration was recorded for *A. viridis* (0.09%, 0.08%, and 0.10%, respectively) and lowest for *L. salicifolia* (0.04%, 0.04%, and 0.05%, respectively). Throughout the year and in the dry season, highest potassium was recorded for *S. americanum* (4.88% and 4.98%, respectively) and lowest for *L. salicifolia* (0.86% and 0.77%, respectively). In the wet season, highest potassium was recorded for *A. viridis* (4.92%) and lowest for *Z. jujuba* (1.05%). Throughout the year and in both the dry and wet seasons, highest phosphorous concentration was recorded for *A. viridis* (0.41%, 0.37%, and 0.51%, respectively) and lowest for *D. indica* (0.07%, 0.06%, and 0.07%, respectively).

Compared to the dry season, dicots showed a higher mean concentration of ADF, NDF, Mg, Na, K and P, and a lower mean concentration of CP, ADL and Ca in the wet season. However, there was no significant difference in the nutrient concentration of dicots between dry and wet seasons. In dicots, the most consumed forage species in the diet of mega- and meso-herbivores viz., *Z. jujuba*, showed a significant difference only in ADL concentration (Mann-Whitney, $p < 0.05$), between the dry and wet seasons.

Table 6.1. Overall (throughout the year) nutrient content (percentage) of major forage plants consumed by mega- and meso-herbivores during 2013-15 in Kaziranga National Park, Assam, India.

Plant species	**Monocot/ Dicot**	**AC (%)**	**CP (%)**	**ADF (%)**	**ADL (%)**	**NDF (%)**	**Ca (%)**	**Mg (%)**	**Na (%)**	**K (%)**	**P (%)**
Alpinia nigra (Gaertn.) Burtt	Monocot	10.63	7.57	55.76	17.91	71.09	0.83	0.21	0.04	2.58	0.09
Calamus tenuis Roxb.	Monocot	8.02	11.42	53.90	19.15	75.03	0.64	0.12	0.03	1.08	0.06
Carex vesicaria L.	Monocot	11.09	8.92	50.27	12.11	71.34	1.11	0.22	0.04	1.59	0.11
Cynodon dactylon (L.) Pers.	Monocot	11.88	7.47	46.70	9.59	73.41	0.86	0.29	0.04	1.50	0.09
Echinochloa crus-galli (L.) P.Beauv.	Monocot	16.17	12.16	40.66	11.22	60.62	1.22	0.44	0.06	1.65	0.13
Hemarthria compressa (L.f.) R.Br.	Monocot	11.20	7.19	50.40	11.08	67.01	0.86	0.57	0.06	1.92	0.20
Imperata cylindrica (L.) Raeusch.	Monocot	8.14	6.63	57.54	11.85	75.34	1.04	0.18	0.03	0.90	0.07
Saccharum spp.	Monocot	8.03	6.02	60.52	11.70	75.21	0.71	0.22	0.03	0.89	0.06
Mean monocots		**10.65**	**8.42**	**51.97**	**13.08**	**71.13**	**0.91**	**0.28**	**0.04**	**1.51**	**0.10**
Standard deviation		**2.74**	**2.25**	**6.36**	**3.47**	**5.10**	**0.20**	**0.15**	**0.01**	**0.57**	**0.05**
Ageratum conyzoides (L.) L.	Dicot	13.84	12.88	49.87	16.76	59.43	1.73	0.48	0.08	2.37	0.22
Amaranthus viridis L.	Dicot	19.31	17.88	35.33	16.80	49.81	2.00	1.08	0.09	4.38	0.41
Dillenia indica L.	Dicot	12.08	6.94	55.85	13.52	66.78	1.43	0.26	0.05	1.30	0.07
Lippia alba (Mill.) N.E.Br. ex Britton & P.Wilson	Dicot	10.75	9.49	53.16	14.40	63.48	1.93	0.29	0.07	1.36	0.19
Litsea salicifolia (Roxburgh ex Nees) Hook. f.	Dicot	5.49	9.05	66.65	13.66	72.42	1.24	0.21	0.04	0.86	0.11
Mallotus nudiflorus (L.) Kulju & Welzen	Dicot	8.37	13.17	46.90	14.24	59.88	1.48	0.24	0.05	1.58	0.24
Oxalis corniculata L.	Dicot	13.68	15.04	46.12	17.11	55.95	1.30	0.45	0.08	1.64	0.22
Solanum americanum Mill.	Dicot	17.26	14.43	48.59	13.44	55.85	1.37	0.36	0.08	4.88	0.27
Ziziphus jujuba Mill.	Dicot	6.27	9.73	62.16	13.97	68.84	1.47	0.25	0.06	0.94	0.10
Mean dicots		**11.89**	**12.07**	**51.62**	**14.88**	**61.38**	**1.55**	**0.40**	**0.07**	**2.15**	**0.20**
Standard deviation		**4.71**	**3.49**	**9.27**	**1.54**	**7.17**	**0.27**	**0.27**	**0.02**	**1.48**	**0.11**
Mean (Monocots & Dicots)		**11.31**	**10.35**	**51.79**	**14.03**	**65.97**	**1.25**	**0.34**	**0.06**	**1.85**	**0.16**
Standard deviation		**3.84**	**3.44**	**7.79**	**2.70**	**7.89**	**0.40**	**0.23**	**0.02**	**1.16**	**0.10**

AC- ash content, CP- crude protein; ADF- acid detergent fibre; ADL- acid detergent lignin, NDF- neutral detergent fibre, Ca- calcium, Mg- magnesium, Na- sodium, K- potassium and P- phosphorous.

Table 6.2. Dry season nutrient content (percentage) of major forage plants consumed by mega- and meso-herbivores during 2013-15 in Kaziranga National Park, Assam, India.

Plant species	Monocot/ Dicot	AC (%)	CP (%)	ADF (%)	ADL (%)	NDF (%)	Ca (%)	Mg (%)	Na (%)	K (%)	P (%)
Alpinia nigra (Gaertn.) Burtt	Monocot	10.68	6.96	57.59	18.96	72.09	0.81	0.21	0.04	2.46	0.08
Calamus tenuis Roxb.	Monocot	8.32	10.87	53.21	19.77	75.76	0.66	0.10	0.03	0.98	0.06
Carex vesicaria L.	Monocot	12.72	8.25	51.69	13.16	69.89	1.07	0.20	0.03	1.38	0.08
Cynodon dactylon (L.) Pers.	Monocot	13.51	6.70	48.24	10.52	72.66	0.86	0.25	0.04	0.99	0.06
Echinochloa crus-galli (L.) P.Beauv.	Monocot	17.31	10.44	41.93	12.79	61.88	0.88	0.33	0.04	1.19	0.10
Hemarthria compressa (L.f.) R.Br.	Monocot	12.65	6.35	52.40	12.50	68.97	0.72	0.47	0.05	1.39	0.17
Imperata cylindrica (L.) Raeusch.	Monocot	8.77	5.59	57.41	13.74	75.94	1.00	0.19	0.03	0.71	0.04
Saccharum spp.	Monocot	9.35	4.75	61.46	13.13	76.15	0.63	0.20	0.03	0.80	0.05
Mean monocots		**11.66**	**7.49**	**52.99**	**14.32**	**71.67**	**0.83**	**0.24**	**0.04**	**1.24**	**0.08**
Standard deviation		**3.00**	**2.20**	**6.09**	**3.26**	**4.82**	**0.16**	**0.11**	**0.01**	**0.55**	**0.04**
Ageratum conyzoides (L.) L.	Dicot	14.25	13.50	49.44	17.41	57.69	1.56	0.45	0.08	2.01	0.18
Amaranthus viridis L.	Dicot	18.84	17.40	35.75	17.04	49.66	1.87	0.95	0.08	4.17	0.37
Dillenia indica L.	Dicot	12.45	6.80	54.53	14.10	66.61	1.58	0.26	0.05	1.23	0.06
Lippia alba (Mill.) N.E.Br. ex Britton & P.Wilson	Dicot	10.39	9.34	54.10	14.80	62.32	2.04	0.28	0.06	1.27	0.18
Litsea salicifolia (Roxburgh ex Nees) Hook. f.	Dicot	5.20	9.02	66.44	13.91	72.10	1.34	0.20	0.04	0.77	0.10
Mallotus nudiflorus (L.) Kulju & Welzen	Dicot	8.43	12.60	45.42	14.14	59.45	1.50	0.23	0.05	1.53	0.22
Oxalis corniculata L.	Dicot	13.77	15.49	44.78	17.44	56.05	1.30	0.45	0.08	1.62	0.21
Solanum americanum Mill.	Dicot	17.35	16.77	46.67	14.19	53.25	1.44	0.38	0.08	4.98	0.26
Ziziphus jujuba Mill.	Dicot	6.42	9.43	61.69	14.94	68.09	1.54	0.27	0.06	0.89	0.09
Mean dicots		**11.90**	**12.26**	**50.98**	**15.33**	**60.58**	**1.58**	**0.38**	**0.06**	**2.05**	**0.19**
Standard deviation		**4.70**	**3.80**	**9.34**	**1.52**	**7.35**	**0.24**	**0.23**	**0.02**	**1.49**	**0.10**
Mean (Monocots & Dicots)		**11.79**	**10.01**	**51.93**	**14.86**	**65.80**	**1.22**	**0.32**	**0.05**	**1.67**	**0.14**
Standard deviation		**3.87**	**3.92**	**7.81**	**2.46**	**8.35**	**0.43**	**0.19**	**0.02**	**1.19**	**0.09**

AC- ash content, CP- crude protein; ADF- acid detergent fibre; ADL- acid detergent lignin, NDF- neutral detergent fibre, Ca- calcium, Mg- magnesium, Na- sodium, K- potassium and P- phosphorous.

Table 6.3. Wet season nutrient content (percentage) of major forage plants consumed by mega- and meso-herbivores during 2013-15 in Kaziranga National Park, Assam, India.

Plant species	Monocot/ Dicot	AC (%)	CP (%)	ADF (%)	ADL (%)	NDF (%)	Ca (%)	Mg (%)	Na (%)	K (%)	P (%)
Alpinia nigra (Gaertn.) Burtt	Monocot	10.50	9.11	51.18	15.30	68.59	0.89	0.22	0.04	2.90	0.14
Calamus tenuis Roxb.	Monocot	7.28	12.80	55.61	17.61	73.21	0.61	0.17	0.04	1.34	0.07
Carex vesicaria L.	Monocot	7.02	10.59	46.71	9.48	74.97	1.21	0.26	0.04	2.13	0.17
Cynodon dactylon (L.) Pers.	Monocot	7.81	9.38	42.84	7.28	75.27	0.89	0.39	0.05	2.79	0.16
Echinochloa crus-galli (L.) P.Beauv.	Monocot	13.32	16.47	37.50	7.30	57.49	2.07	0.72	0.09	2.82	0.20
Hemarthria compressa (L.f.) R.Br.	Monocot	7.57	9.30	45.40	7.52	62.11	1.20	0.83	0.08	3.24	0.28
Imperata cylindrica (L.) Raeusch.	Monocot	6.56	9.24	57.87	7.13	73.82	1.14	0.17	0.04	1.36	0.14
Saccharum spp.	Monocot	4.74	9.19	58.16	8.13	72.87	0.90	0.26	0.05	1.11	0.09
Mean monocots		**8.10**	**10.76**	**49.41**	**9.97**	**69.79**	**1.11**	**0.38**	**0.05**	**2.21**	**0.16**
Standard deviation		**2.64**	**2.63**	**7.54**	**4.12**	**6.61**	**0.44**	**0.26**	**0.02**	**0.84**	**0.07**
Ageratum conyzoides (L.) L.	Dicot	12.81	11.33	50.94	15.12	63.79	2.16	0.57	0.10	3.27	0.32
Amaranthus viridis L.	Dicot	20.49	19.09	34.28	16.19	50.17	2.30	1.40	0.10	4.92	0.51
Dillenia indica L.	Dicot	11.17	7.26	59.15	12.06	67.21	1.06	0.24	0.05	1.49	0.07
Lippia alba (Mill.) N.E.Br. ex Britton & P.Wilson	Dicot	11.62	9.87	50.82	13.39	66.38	1.65	0.31	0.08	1.58	0.22
Litsea salicifolia (Roxburgh ex Nees) Hook. f.	Dicot	6.20	9.11	67.16	13.05	73.23	1.01	0.23	0.05	1.07	0.16
Mallotus nudiflorus (L.) Kulju & Welzen	Dicot	8.21	14.61	50.60	14.50	60.96	1.43	0.27	0.06	1.70	0.28
Oxalis corniculata L.	Dicot	13.47	13.91	49.47	16.29	55.69	1.32	0.47	0.08	1.70	0.25
Solanum americanum Mill.	Dicot	17.02	8.58	53.39	11.58	62.36	1.19	0.30	0.09	4.64	0.29
Ziziphus jujuba Mill.	Dicot	5.88	10.46	63.33	11.52	70.72	1.28	0.21	0.07	1.05	0.12
Mean dicots		**11.87**	**11.58**	**53.24**	**13.74**	**63.39**	**1.49**	**0.44**	**0.08**	**2.38**	**0.25**
Standard deviation		**4.82**	**3.69**	**9.50**	**1.87**	**7.21**	**0.46**	**0.38**	**0.02**	**1.51**	**0.13**
Mean (Monocots & Dicots)		**10.10**	**11.19**	**51.44**	**11.97**	**66.40**	**1.31**	**0.41**	**0.07**	**2.30**	**0.20**
Standard deviation		**4.30**	**3.16**	**8.60**	**3.60**	**7.48**	**0.48**	**0.32**	**0.02**	**1.21**	**0.11**

AC- ash content, CP- crude protein; ADF- acid detergent fibre; ADL- acid detergent lignin, NDF- neutral detergent fibre, Ca- calcium, Mg- magnesium, Na- sodium, K- potassium and P- phosphorous.

Table 6.4. Seasonal differences in the nutrient content of major forage consumed by mega- and meso-herbivores during 2013-15 in Kaziranga National Park, Assam, India.

Forage	Season	Parameter	Mann-Whitney (U)	p
Monocot	Between dry and wet seasons	AC	9	**0.015**
		CP	11	**0.028**
		ADF	24	0.442
		ADL	12	**0.038**
		NDF	27	0.645
		Ca	14	0.065
		Mg	22	0.328
		Na	9	**0.015**
		K	11	**0.028**
		P	9	**0.015**
Dicot	Between dry and wet seasons	AC	38	0.863
		CP	37	0.796
		ADF	32	0.489
		ADL	22	0.113
		NDF	31	0.436
		Ca	28	0.297
		Mg	38	0.863
		Na	26	0.222
		K	33	0.546
		P	27	0.258
Monocot and Dicot	Throughout the year	AC	109	0.237
		CP	80	**0.027**
		ADF	138	0.851
		ADL	86	**0.046**
		NDF	47	**0.001**
		Ca	26	**0.000**
		Mg	91	0.070
		Na	42	**0.000**
		K	115	0.330
		P	61	**0.003**
Monocot and Dicot	Dry season	AC	34	0.847
		CP	10	**0.012**
		ADF	31	0.630
		ADL	18	0.083
		NDF	7	**0.005**
		Ca	0	**0.001**
		Mg	18	0.083
		Na	4	**0.002**
		K	22	0.178
		P	8	**0.007**
Monocot and Dicot	Wet season	AC	19	0.102
		CP	33	0.773
		ADF	27	0.386

Forage	Season	Parameter	Mann-Whitney (U)	p
		ADL	16	0.054
		NDF	17	0.068
		Ca	15	**0.043**
		Mg	29	0.501
		Na	13	**0.027**
		K	36	1.000
		P	19	0.102
Monocot and Dicot	Between dry and wet seasons	AC	101	0.140
		CP	110	0.245
		ADF	143	0.973
		ADL	84	**0.038**
		NDF	139	0.865
		Ca	132	0.683
		Mg	120	0.413
		Na	84	**0.038**
		K	83	**0.034**
		P	86	**0.045**

AC- ash content, CP- crude protein; ADF- acid detergent fibre; ADL- acid detergent lignin, NDF- neutral detergent fibre, Ca- calcium, Mg- magnesium, Na- sodium, K- potassium and P- phosphorous.

6.3.3 Nutrient Content: Comparison Between Monocots and Dicots

Throughout the year and in both the dry and wet seasons, dicots with their high CP and mineral concentrations were more nutritious than monocots. While there were significant changes in the nutritional quality parameters of monocots from the dry to the wet season, no significant seasonal changes in the nutritional quality of dicots were recorded. Throughout the year, there were significant differences in CP, ADL, NDF, Ca, Na and P concentrations (Mann-Whitney, $p< 0.05$), between monocots and dicots (Table 6.4). In the dry season, there were significant differences in CP, NDF, Ca, Na and P concentrations (Mann-Whitney, $p< 0.05$) between monocots and dicots, while in the wet season, there were significant differences in Ca and Na concentrations (Mann-Whitney, $p< 0.05$). The concentrations of ADL, Na, K and P (Mann-Whitney, $p< 0.05$) in monocots and dicots differed significantly between the dry and wet seasons.

6.3.4 Nutrient Content: Factors Influencing Seasonal Forage Use by Large Herbivores

The top model selection for forage consumption revealed that CP and ADL content influenced rhino, swamp deer and sambar forage use throughout the year. Similarly, Ca and ADL influenced forage use by buffalo and hog deer. NDF and Na concentration influenced elephant's forage use. In the dry season, CP and ADL content governs forage use by rhino and sambar, while Ca and ADL govern forage use by buffalo, swamp deer and hog deer, and NDF and Na concentration govern forage use by elephant (Table 6.5). In the wet season, AC and ADL concentrations influenced the major forage use by mega- and meso-herbivores.

Table 6.5. Model selection of major forage consumed by mega- and meso-herbivores during 2013-15 in Kaziranga National Park, Assam, India.

Study Species	Season	Model	Ak. wt	AICc	delta AICc	df	Log L
Greater One-horned Rhino	Overall	CP+ADL	0.82	2.1	0	4	4.62
		CP+ADL+Ca	0.16	5.3	3.25	5	5.06
		CP+ADL+Ca+P	0.02	10.2	8.07	6	5.12
	Dry	CP+ADL	0.78	2.1	0	4	4.62
		CP+ADL+Ca	0.19	4.9	2.81	5	5.27
		CP+ADL+Ca+Na	0.03	8.6	6.5	6	5.91
	Wet	ADL+AC	0.88	0.5	0	4	5.43
		ADL+AC+P	0.11	4.6	4.12	5	5.44
		ADL+AC+P+NDF	0.01	9	8.52	6	5.71
Asian Elephant	Overall	NDF+Na	0.87	3.8	0	4	3.77
		NDF+Na+P	0.12	7.8	3.99	5	3.83
		NDF+Na+P+Ca	0.01	12.3	8.48	6	4.06
	Dry	NDF+Na	0.88	5.4	0	4	2.95
		NDF+Na+P	0.11	9.5	4.11	5	2.95
		NDF+Na+P+Mg	0.01	14.4	8.97	6	3.00
	Wet	AC+ADL	0.88	1.2	0	4	5.05
		AC+ADL+P	0.11	5.3	4.1	5	5.06
		AC+ADL+P+K	0.01	10.2	8.99	6	5.09
Asiatic Wild Buffalo	Overall	ADL+Ca	0.86	1.5	0	4	4.93
		ADL+Ca+CP	0.12	5.4	3.95	5	5.02
		ADL+Ca+CP+NDF	0.02	9	7.58	6	5.68
	Dry	ADL+Ca	0.85	0.6	0	4	5.35
		ADL+Ca+CP	0.11	4.7	4.08	5	5.37
		ADL+Ca+CP+Na	0.04	6.9	6.29	6	6.74
	Wet	ADL+AC	0.61	1.7	0	4	4.83
		ADL+AC+ADF	0.36	2.7	1.04	5	6.37
		ADL+AC+ADF+P	0.03	7.7	5.98	6	6.37
Swamp Deer	Overall	ADL+CP	0.64	8.8	0	4	1.28
		ADL+CP+Ca	0.32	10.2	1.39	5	2.65
		ADL+CP+Ca+NDF	0.04	14.2	5.47	6	3.08
	Dry	ADL+Ca	0.85	5.4	0	4	2.97
		ADL+Ca+CP	0.11	9.4	4.03	5	3.02

Study Species	Season	Model	Ak. wt	AICc	delta AICc	df	Log L
		ADL+Ca+CP+NDF	0.04	11.6	6.21	6	4.40
	Wet	ADL+AC	0.77	5.7	0	4	2.79
		ADL+AC+P	0.15	9	3.21	5	3.25
		ADL+AC+P+NDF	0.07	10.5	4.78	6	4.94
Hog Deer	Overall	ADL+Ca	0.85	9	0	4	1.18
		ADL+Ca+CP	0.13	12.8	3.79	5	1.35
		ADL+Ca+CP+NDF	0.03	15.9	6.97	6	2.23
	Dry	ADL+Ca	0.80	9.9	0	4	0.72
		ADL+Ca+CP	0.11	14	4.06	5	0.75
		ADL+Ca+CP+Na	0.09	14.2	4.34	6	3.08
	Wet	ADL+AC	0.84	5.8	0	4	2.79
		ADL+AC+CP	0.14	9.3	3.54	5	3.08
		ADL+AC+CP+Ca	0.01	14.2	8.41	6	3.11
Sambar	Overall	ADL+CP	0.88	5.8	0	4	2.78
		ADL+CP+P	0.11	9.9	4.12	5	2.79
		ADL+CP+P+NDF	0.01	14.8	9.01	6	2.81
	Dry	ADL+CP	0.86	7	0	4	2.16
		ADL+CP+ADF	0.13	10.9	3.87	5	2.28
		ADL+CP+ADF+Ca	0.01	15.5	8.43	6	2.47
	Wet	ADL+AC	0.87	2.7	0	4	4.31
		ADL+AC+P	0.11	6.8	4.1	5	4.31
		ADL+AC+P+NDF	0.01	11	8.29	6	4.69

AC- ash content, CP- crude protein; ADF- acid detergent fibre; ADL- acid detergent lignin, NDF- neutral detergent fibre, Ca- calcium, Mg- magnesium, Na- sodium, K- potassium and P- phosphorous.

The correlogram revealed that throughout the year, rhino significantly consumed forage with low CP and ADF concentrations; elephant significantly consumed forage rich in NDF and low in Ca, Na and P; and buffalo, swamp deer, and hog deer significantly consumed forage with low ADL content (Figure 6.1). In the dry season, rhino significantly consumed forage with low CP; elephant significantly consumed forage rich in NDF and low in Na and P; buffalo and swamp deer significantly consumed forage with low CP, ADL and Ca; and hog deer significantly consumed forage with low ADL concentration (Figure 6.2). In the wet season, rhino, buffalo, swamp deer, hog deer and sambar significantly consumed forage with low ADL concentration, whereas elephant significantly consumed forage with low AC (Figure 6.3).

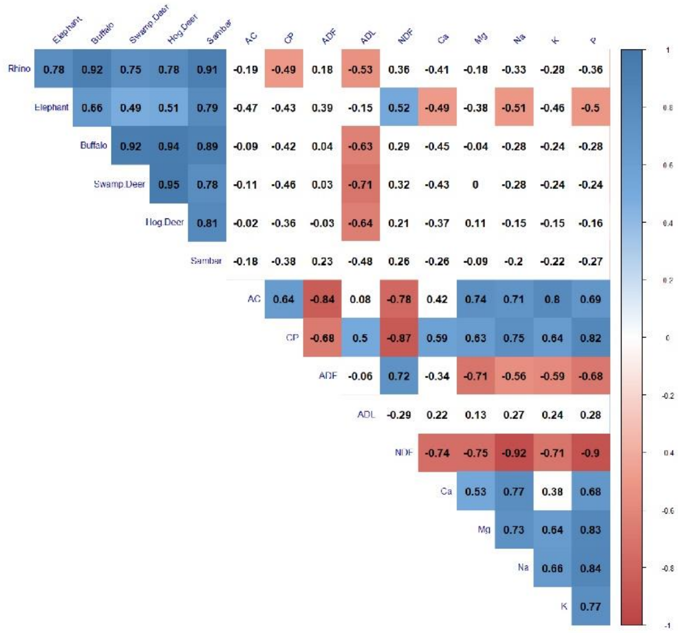


Figure 6.1. Correlogram showing the relationship between nutrient parameters of the major forage consumed by mega- and meso-herbivores throughout the year. The values within the white boxes represent insignificant correlation ($p > 0.05$), whereas the values within the red (negative correlation) and blue (positive correlation) boxes represent significant correlation ($p < 0.05$).

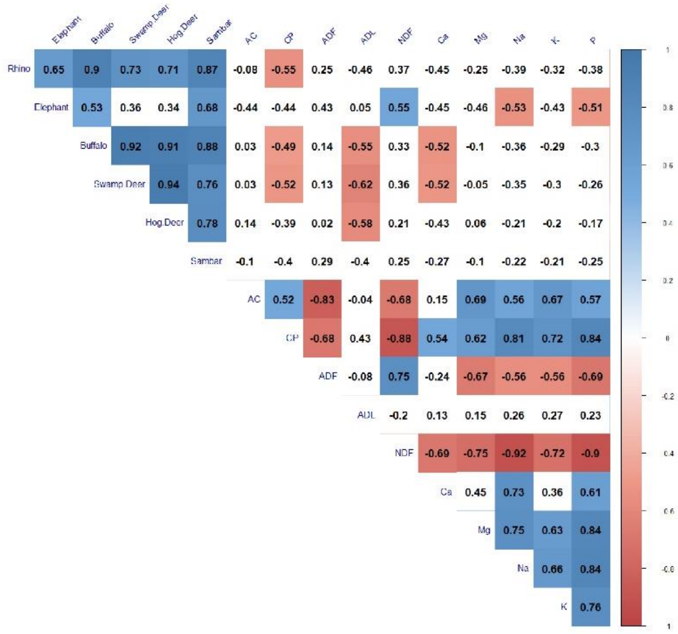


Figure 6.2. Correlogram showing the relationship between nutrient parameters and the major forage consumed by mega- and meso-herbivores in the dry season. The values within the white boxes represent insignificant correlation ($p > 0.05$), whereas the values

within the red (negative correlation) and blue (positive correlation) boxes represent significant correlation ($p < 0.05$).

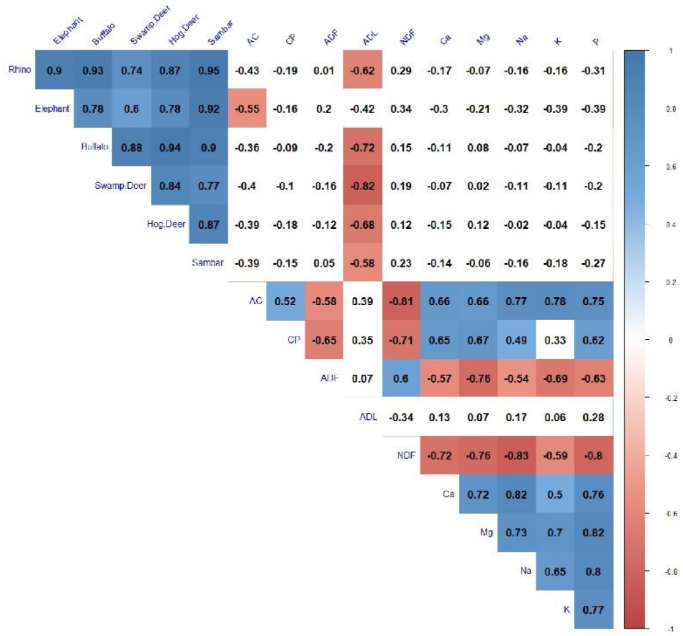


Figure 6.3. Correlogram showing the relationship between nutrient parameters and the major forage consumed by mega- and meso-herbivores in the wet season. The values within the white boxes represent insignificant correlation ($p > 0.05$), whereas the values within the red (negative correlation) and blue (positive correlation) boxes represent significant correlation ($p < 0.05$).

6.4 Discussion

Forage and habitat use patterns of mega- and meso-herbivores are related to variations in the nutrient content as it changes the forage quality during different seasons (Banerjee, 2001). This study has shed light on the physico-chemical composition of the major forage, including monocots and dicots, consumed by mega- and meso-herbivores in KNP during the dry and wet seasons. The nutrient analysis revealed that the major forage species consumed throughout the year by mega- and meso-herbivores were more nutritious in the wet season. In the wet season, freshly sprouted and green graminoids have a thin cell wall and higher protein as compared to older tissues and stems of grasses and small dicotyledons where cell walls are thickened and lignified, and the protein content is lower and less accessible (Banerjee, 2001). This study revealed that the most consumed monocot plants, *Saccharum* spp. (monocot contributing >9% to mega- and meso-herbivores' diet) and *H. compressa* (monocot contributing >3% to mega- and meso-herbivores' diet) were more nutritious in the wet season. Possibly due to controlled burning and rainfall, monocots with high CP and mineral content, and low AC, fibre and lignin content were more nutritious and digestible in the wet season compared to the dry season. The studies conducted in grasslands of Africa and Asia have also provided scientific evidence of graminoids being nutritive and digestible (Ahrestani et al., 2011; Arnold et al., 2014; Veldhuis et al., 2016; Thapa et al., 2021).

The present study also revealed that, irrespective of the season, dicots, including the most consumed *Z. jujuba* (dicot contributing >4% to mega- and meso-herbivores' diet), were nutritious. These dicots were characterized by a high concentration of CP and minerals (Ca, Mg, Na, K and P), and a low concentration of ADF and NDF. Compared to monocots, dicots had a relatively high crude protein and mineral (Ca, Mg, Na, K and P) content, and low AC and fibre content (ADF and NDF). The results from the study were supported by Kos et al. (2011), which also reported significant change only in the nutrient parameters of monocots, not for the dicots. With their nutritional qualities, both monocots and dicots play a crucial role in fulfilling the nutrient requirement of mega- and meso-herbivores in KNP.

Forage use by herbivores is influenced by various nutrient parameters, including crude protein and fibre content (Kar-Gupta & Kumar, 1991). Lignin is one of the major digestion inhibitors present in plant material, which interferes with the digestive process among herbivores (Manjrekar, 2015). The GLM and correlation analysis revealed that irrespective of seasons, lignin (ADL), fibre (NDF), ash content and crude protein were the main predictors of the major forage consumed by mega- and meso-herbivores. Herbivores, while foraging on nutrient-rich forage, might consume chemically defended forage, resulting in the consumption of toxic plant secondary metabolites (tannins and polyphenols). The detoxification of the secondary metabolites requires more energy. Therefore, to avoid toxic plant secondary metabolites, herbivores might feed on low nutrient quality forage (Parikh et al., 2017). Minson (1976) has reported that herbivores can obtain their nutrition from fibres such as cellulose (unlignified) and hemicellulose (partially lignified). A high fibrous diet increases digestive efficiency by increasing the retention time of the food in the gut (Owen-Smith, 1988). With their large body sizes, mega-herbivores have a higher daily intake and are more sensitive than meso-herbivores to a decrease in the forage quantity, which makes them feed on poor-quality plants (Bell, 1971). Meso-herbivores have a higher metabolic rate that affects their protein requirement as well as their energy requirements. Thus, meso-herbivores have the advantage of more time to meet their daily requirements and can be more selective in their feeding choice. Prins (1996) has suggested that ruminants might increase their grazing time to compensate for the lower dietary quality when the available forage has poor quality, especially low crude protein content. Besides differences in the body sizes of mega- and meso-herbivores, gut physiology, muzzle size and jaw structure might influence their forage selection (Bell, 1970; Sinclair, 1979; Demment & Van Soest, 1985, Banerjee, 2001). The information provided in this study might be useful in providing the proper care to the mega- and meso-herbivores that exist in the wild, are rescued, or kept in captivity. This will also help in updating the management plan, focusing on the conservation of large herbivore species not only in KNP but also in other riverine alluvial floodplains.

6.5 Conclusion

A major struggle for herbivores is acquiring forage that is easily accessible and fulfils their nutrient requirement (Clauss et al., 2013). Nutrients such as energy, minerals, vitamins, protein and fibre play a fundamental role in the development and growth of herbivores (McDowell, 1985). In conclusion, monocots consumed by mega- and meso-herbivores were found to be more nutritious and digestible in the wet season, while dicots were nutritious irrespective of season. Therefore, season only affects the forage quality of monocots. Despite the availability of nutritious dicots, the mega- and meso-herbivores feed more on monocots due to their nutrient content and availability throughout the year and possibly due to easy accessibility, availability of water closer to the foraging sites and lower predation risk. Throughout the year and in the resource-limited dry season, the forage selection by mega- and meso-herbivores can be predicted with ADL content as it showed a significant negative relationship with the forage used by SLH, excluding the elephant. The elephant's forage selection can be predicted with NDF content, as it showed a significant positive relationship with its forage use. In the wet season, ash content was one of the major predictors of forage selection by mega- and meso-herbivores, as it showed a significant negative relationship with its forage use. In the future, any changes in the availability, accessibility and nutrient content of the major forage plants might affect the population of these mega- and meso-herbivores. Therefore, further experimental studies explaining the factors responsible for feeding choices and the impact of meg-a and meso-herbivores on plant vegetation composition are required to understand the community vegetation dynamics in KNP.

CHAPTER 7
SYNTHESIS AND MANAGEMENT RECOMMENDATIONS

7.1 Introduction

In India, the riverine alluvial grasslands of the Ganga and Brahmaputra floodplains result from frequent flooding, which results in shifting channel patterns accompanied by erosion and siltation (Vasu & Singh, 2015). The globally renowned Kaziranga National Park in the Brahmaputra floodplains is one of the crucial riverine alluvial grassland ecosystems in the world. With about 64% of the grasslands (61% tall grassland and 3% short grassland), 28% of woodlands and 6% of waterbodies, it supports one of the last remaining populations of the greater one-horned rhino, Asiatic wild buffalo and eastern swamp deer, and significant populations of the Asian elephant, hog deer and sambar (Vasu & Singh, 2015). Besides this, gaur and barking deer have also been reported from the Kaziranga. The riverine alluvial grasslands of Kaziranga are confronted with a myriad of problems such as shrinkage in size and depth due to heavy siltation, choking of water bodies by water hyacinths and weed infestation in the drawdown areas, which unless addressed, may affect grassland integrity and the associated fauna (Vasu & Singh, 2015).

In the last few decades, climate change and habitat loss have impacted biological systems. It is estimated that since 1970, 58% of animal populations have faced the threat of extinction (WWF, 2016; Gebremedhin et al., 2016; Spooner et al., 2016). Climate change poses a serious threat to herbivores directly by influencing rainfall and temperature, and indirectly through the occurrence of extreme climate events such as fires, floods and droughts, which may affect the availability and quality of forage and threaten their fitness, survival, migration and reproductive success (Texeira et al., 2012; Kupika et al., 2018). Globally, riverine alluvial grasslands in floodplains are threatened, primarily due to the fragmentation and degradation of such habitats (Joyce et al., 2016). Consequently, in most parts of the world, rhinos and buffalo no longer coexist with elephants, swamp deer, hog deer and sambar (Pradhan et al., 2008). Therefore, little is known about the degree of determinants of inter- and intra-specific diet variation among these herbivores. The present study was conducted in KNP to provide information on the foraging ecology of SLH and the guild of mega- and meso-herbivores, including their dietary composition, resource partitioning, and quantity and quality of forage. In sympatric herbivores, the foraging patterns provide insights into the utilization patterns of the occupied habitat, which is important for making assumptions about the behaviour, physiology, morphology and population dynamics of predators, prey and competitors (Brodeur et al., 2017).

7.2 Key Research Findings

7.2.1 Diet Composition

- The mega- and meso-herbivores grazed more during the wet season, although browse also formed a significant portion of the diet; indicating that both mega- and meso-herbivores were grazers and mixed feeders.
- Compared to other herbivores, rhino, buffalo, swamp deer and hog deer were more involved in grazing during both the dry and wet seasons.
- Compared to other herbivores, the diet of rhino, elephant and sambar consisted more of browse.
- From the dry to wet season, elephant and sambar shift their diet from browsing to grazing, which indicates their flexibility in utilization of available forage.
- Among monocots, *Saccharum* spp. (tall grass) and *Hemarthria compressa* (short grass), and among dicots, *Ziziphus jujuba* were majorly consumed forage species that play a crucial role in meeting the dietary requirements of both mega- and meso-herbivores, highlighting the importance of grasslands in fulfilling the dietary needs of both mega- and meso-herbivores.

7.2.2 Forage Preference and Overlap

- From the dry to wet season, probably due to precipitation, there is a significant increase in forage biomass, which suggests that season influences forage biomass available for large herbivores.
- From the dry to wet season, mega-herbivores shift their most preferred forage from browse to graze, and meso-herbivores, especially swamp deer, showed

more affinity toward grasses. This suggests that forage availability contributes to the forage preference of large herbivores.

- Irrespective of season, the invasive shrub *Mimosa* spp. was totally avoided by meso-herbivores, whereas mega-herbivores fed on *Mimosa* spp. due to its high availability and, possibly, nutrient quality (Guyton et al., 2020). Irrespective of season, the invasive climber *M. umbellata* was avoided by SLH. Invasive climber *M. micrantha* was preferred by buffalo, irrespective of season, and by rhino and elephant, overall and in the dry season. It was avoided by swamp deer and hog deer, irrespective of season, and by sambar in the dry and wet seasons. A reason for its consumption might be its entanglement with the principal forage *Saccharum* spp. and other forage grass species, and its availability throughout the year (Ram, 2008).
- The proliferation and growth of invasives like *Mimosa* spp., *M. micrantha* and *M. umbellata*, have the potential to impact the foraging ecology of herbivores. Thus, grassland-based effective management interventions such as invasive uprooting followed by reseeding of the preferred and principal forage are needed to fulfil the nutritional requirements of herbivores. In future, more scientific studies are needed to study the physiological impacts on large herbivores from feeding on invasives.
- Irrespective of season, biologically significant dietary overlap (>0.6) was recorded among SLH, and mega- and meso-herbivores. This is attributed to sufficient forage availability and differences in foraging strategies and resource segregation at a spatio-temporal scale.
- The study's findings are significant as no other research has investigated inter- and intra-specific differences in the diet among SLH, and mega and meso-herbivores with respect to resource availability within the riverine alluvial grasslands of the Brahmaputra floodplains. With the world's largest global population of rhino and buffalo, and a significant population of elephant, swamp deer, hog deer and sambar, KNP is a key protected area in Asia. The results of this chapter may be useful for the long-term management of the habitat of Asia's largest large herbivores.

7.2.3 Nutrient Dynamics of Majorly Consumed Forage

- Monocots consumed by mega- and meso-herbivores were found to be more nutritious and digestible in the wet season, while dicots were nutritious irrespective of season. Therefore, season only affects the forage quality of monocots.

- Despite the availability of nutritious dicots, mega- and meso-herbivores feed more on monocots due to their nutrient content and availability throughout the year and possibly due to easy accessibility, availability of water closer to the foraging sites and low predation risk.

- Throughout the year and in the resource-limited dry season, the forage selection by mega- and meso-herbivores, excluding the elephant, can be predicted with the ADL content as it showed a significant negative relationship with the forage used. Forage selection by elephant can be predicted with the NDF content as it showed a significant positive relationship with its forage use. In the wet season, ash content was a major predictor of forage selection by mega- and meso-herbivores, as it showed a significant negative relationship with its forage use.

- In the future, any changes in the availability, accessibility and nutrient content of the major forage plants might affect the populations of these mega- and meso-herbivores. Therefore, further experimental studies explaining the factors responsible for the feeding choices and the impact of mega- and meso-herbivores on plant vegetation composition are required to understand the plant animal interaction in KNP.

7.3 Conservation Implications

- In KNP, the ongoing processes of succession and invasion threaten the grasslands, which in the future might affect the availability of the principal forage plants consumed by mega- and meso-herbivores. Therefore, to maintain the herbivores' population in KNP, it is suggested to retain the grassland integrity by formulating effective grassland-specific and plant-specific management plans, which fulfils their dietary needs.

- This study highlights biologically significant dietary overlap among SLH, which combined with the increasing population of mega- and meso-herbivores in KNP, as evidenced by the animal census from 1966 to 2014, might threaten their coexistence in the future by increasing competition for available resources. Therefore, based on the dietary needs, it is crucial to evaluate the stocking density of herbivores at multispecies and individual levels.

- Irrespective of the availability of nutritious dicots, both mega- and meso-herbivores feed more on monocots, indicating that these grasslands play a crucial role in fulfilling the dietary need of the herbivores'. Despite being subjected to combinations of herbivory, and management practices such as annual controlled burning and manual uprooting of globally noxious invasive, these grasslands are threatened by woody invasion, resulting in the conversion of grasslands into forests. Therefore, there is an emerging need to conduct more scientific evidence based studies to study the impact of herbivory, prescribed burning and manual invasive uprooting on the grasslands for the long-term coexistence of SLH.

- In the current era of polycrisis, including climate change and habitat degradation, the information gathered from this study is useful in providing key scientific and ecological insights on globally threatened large herbivores and formulating informed policy and management interventions that require baseline information on the species inhabiting the area. Based on the present study, Park managers can formulate:

    a) effective herbivore species-specific conservation action plans.
    b) conservation strategies to address the feeding ecology of large herbivores.
    c) strategies to improve herbivore species-specific relocation programmes.

7.4 Management Recommendations

- **Livestock-Wildlife Interaction:** The tall grassland species, *Saccharum* spp., was the highest consumed forage of SLH as well as the highest contributing species in terms of forage biomass. These tall grasslands are under pressure from livestock grazing, which can potentially reduce the availability of resources for SLH, increase the probability of transmission of zoonotic diseases, and alter the vegetation structure due to the preponderance of invasive plant species. Therefore, more scientific evidence-based studies are required to identify the- a) areas that are highly vulnerable to livestock-wildlife interactions, b) impact of livestock overgrazing on the vegetation structure, c) impact of overgrazing pressure on the community dynamics of large herbivores, and d) herbivore species-specific risk from the transmission of zoonotic disease. In future, these studies would provide the baseline information to manage livestock-wildlife interactions based on which informed management interventions could be formulated. Besides this, fences can be constructed to protect highly vulnerable areas, and regular monitoring of these locations can be undertaken.
- **Wetland Management:** In KNP, perennial water sources, locally known as *beels*, are the primary source of drinking water in the Park and provide crucial habitat to large herbivores like rhinos, elephants, buffaloes, swamp deer, hog deer and sambar. Apart from drinking water, herbivores use *beels* to wallow and create a second skin layer to protect against insects and mosquitoes. Over three decades, primarily from 1970 to 2001, the extent of *beels* decreased from 33.8 km^2 to 19.5 km^2, and the number of *beels* reduced from 266 to 110 due to heavy siltation (brought up by floods), and choking due to water hyacinth (*Eichhornia crassipes*) and weed infestation (Geethanjali, 2017). Availability of water might be a major factor that governs forage utilization by herbivores, as tall and short grasses (major forage) are generally distributed in the immediate vicinity of these perennial water sources, around which herbivores congregate. Therefore, increasing the extent of water bodies in the Park may potentially reduce the chances of herbivores competing for the same resources (due to increasing

population) by creating an even distribution of herbivores in the landscape, which would reduce the adverse impact on vegetation structure from a patchily distributed high herbivore population in the Park. De-siltation of the existing choked waterbodies, removal of water hyacinth and weeds, and regular monitoring of the *beels*, specially post-flood, can be helpful in ensuring the long-term management and conservation of SLH.

- **Home Range:** Low forage availability during the dry season tends to lower the quality and quantity of intake. Hence, animals usually respond to such variability by moving to areas where forage is more readily available. With the evident increasing population of SLH, elephants, with their large home ranges, have more opportunity to explore mixed habitats (woodland, tall and short grasslands) for forage and reduce chances of competition, while other herbivores like rhino, buffalo, swamp deer and hog deer, with their smaller home ranges, are more vulnerable to competing for the similar resources. Therefore, it is necessary to investigate the home ranges of the herbivores in the KNP during the dry and wet seasons, and to gather scientific evidence on herbivore species that are more vulnerable to competition to ensure the long-term coexistence of these large herbivores.
- **Prescribed Burning:** Annual controlled burning is practiced as a tool for habitat management by the park authority, which maintains the natural processes of succession, creates a mosaic of heterogeneity, and provides high-quality forage resources for large herbivores. However, it was observed that local people aware of burning practices recreationally burn the tall grasslands in an unscientific manner, which not only threatens the wildlife but also potentially reduces the forage availability. Therefore, a proper protocol for surveillance and penalty should be implemented to dissuade tourists from burning the tall grasslands.
- **Restore Corridor Connectivity**: Corridors plays a crucial role in maintaining the genetic diversity and health of wildlife populations, as it allows animals to access diverse habitat for foraging and other activities. Earlier, the riverine alluvial grasslands of Kaziranga and the adjoining forest of Karbi Anglong formed an important ecological unit and provided an ideal habitat for the

wildlife of Kaziranga, including large herbivores. The gradual expansion of human settlements along with National Highway 37 in the Kaziranga-Karbi wildlife corridor has fragmented the connectivity of natural forests and wild habitats, which has not only significantly increased the chances of poaching and vehicle collisions, but has also affected the seasonal movement of large bodied animals. One of the impacted species, Gaur (*Bos gaurus*), which is not a resident animal of Kaziranga, once used to migrate from the nearby Karbi Anglong Hills to KNP during winter. The fragmentation of this corridor has affected the seasonal movement of gaur, who have completely stopped migrating to Kaziranga. With the increasing population of large herbivores, the demand for space and resources also increases, which in future might result in competition for similar space and resources. Therefore, the long-term conservation of herbivores in KNP requires a management plan to restore corridor connectivity, and more scientific studies to identify and prioritize the crucial potential corridors.

- **Research and Monitoring Cell**: In KNP, anti-poaching activities and protecting the globally threatened fauna have always been a priority, resulting in the sidelining of the research and monitoring activities. KNP, being a Wildlife Sanctuary, National Park, World Heritage Site, Elephant Reserve and Tiger Reserve, has immense conservation significance; therefore, there is an urgent need to establish a research and monitoring cell to study the:
    a) factors accelerating and arresting the grassland successional processes, including the- i) role of mega- and meso-herbivores, ii) impact of management interventions such as controlled burning and invasive removal, and iii) impact of climate change induced frequent floods.
    b) rate of succession of grassland into woodland, which should focus on grassland-specific research, especially for short grasslands, as compared to tall grasslands, less scientific and management focus has been given to short grasslands, especially with respect to herbivory and invasive management.

c) extent of invasion and identification of major invasive species in both the short and tall grasslands, and the impact of these invasives on herbivores' and their habitats to formulate invasive species-specific management strategies, including manual and biological removal.
d) extent of dependency of local communities on KNP resources for fodder, fuelwood and fish, and the extent of extraction of the principal forage species of large herbivores such as *Saccharum* spp., *Hemarthria compressa*, *Cynodon dactylon*, *Imperata cylindrica* and *Ziziphus jujuba*, including its impact on the forage availability of large herbivores.
e) detailed inventorization and up-gradation of the flora of KNP to ease the research process and formulation of management interventions. The primary work on the flora of KNP was conducted in 1985 and early 2000s, which is inaccessible and does not consider the latest additions to the Park. Any increase or decrease in the Park area affects the vegetation composition, necessitating periodic up-gradation of the flora.
f) detailed inventorization and up-gradation of the present status of the fauna in KNP, to identify globally threatened fauna, apart from iconic species like rhino, elephant and tiger, for which species-specific effective management and conservation interventions can be formulated. Most of the available information is fragmented, inaccessible and old, and additionally, the lack of scientific records on the present status of rare, endangered and threatened species such as Gangetic river dolphin (*Platanista gangetica*), gharial (*Gavialis gangeticus*), dhole (*Cuon alpinus*), hispid hare (*Caprolagus hispidus*) and honey badger (*Mellivora capensis*) makes it difficult to validate their existence in the Park.
g) population, mortality and threats to the globally threatened fauna present in KNP, as regular population and ecological monitoring are limited to rhinos, sidelining other important fauna.

h) carrying capacity of the large herbivores and other globally threatened fauna for their long-term coexistence in the Park.

i) feeding ecology of other herbivores and carnivores, which can be assessed using non-invasive faecal DNA analysis as it is less time consuming and reduces the chances of misidentification and observer biasness.

LITERATURE CITED

Abrams, P. (1980). Some comments on measuring niche overlap. *Ecology*, *61* (1), 44-49.

Ahmed, M. F., Das, A., Prasad Lahkar, B., Nath Sharma, R., & Kumar Vasu, N. (2005). *Inventory of Herpetofauna and Evaluation of their Conservation Status in the Kaziranga National Park with Observations on Impact of Grassland Burning, Assam, India.* Final summary report.

Ahrestani, F. S. (2009). *Asian Eden: Large Herbivore Ecology in India*. Doctoral Thesis, Wageningen University and Research.

Ahrestani, F. S., & Sankaran, M. (2016). Introduction: The large herbivores of South and Southeast Asia—A prominent but neglected guild. In Ahrestani, F. and S., & Sankaran, M. (Eds.). *The ecology of large herbivores in South and Southeast Asia* (pp. 1-13). Springer, Dordrecht.

Ahrestani, F. S., Heitkönig, I. M., & Prins, H. H. (2012). Diet and habitat-niche relationships within an assemblage of large herbivores in a seasonal tropical forest. *Journal of Tropical Ecology*, *28*(4), 385-394.

Ahrestani, F. S., Heitkönig, I., & Prins, H. H. (2011). Herbaceous production in South India—limiting factors and implications for large herbivores. *Plant and soil*, *349*(1), 319-330.

Ahrestani, F. S., Heitkönig, I., Matsubayashi, H., & Prins, H. H. (2016). Grazing and browsing by large herbivores in South and Southeast Asia. In Ahrestani, F. and S., & Sankaran, M. (Eds.). *The Ecology of Large Herbivores in South and Southeast Asia* (pp. 99-120). Springer, Dordrecht.

Allen, S. E., Grimshaw, H. M., Parkinson, J. A., & Quarmby, C. (1974). *Chemical Analysis of Ecological Materials* (2^{nd} ed.). Blackwell Scientific Publications. 565pp.

Anderson, M. J., & Walsh, D. C. I. (2013). PERMANOVA, ANOSIM, and the Mantel test in the face of heterogeneous dispersions: What null hypothesis are you testing?. *Ecological Monographs*, *83*(4), 557-574.

Areendran, G., Raj, K., Sharma, A., Bora, P. J., Sarmah, A., Sahana, M., & Ranjan, K. (2020). Documenting the land use pattern in the corridor complexes of Kaziranga National Park using high resolution satellite imagery. *Trees, Forests and People*, *2*, 100039.

Arnold, S. G., Anderson, T. M., & Holdo, R. M. (2014). Edaphic, nutritive, and species assemblage differences between hotspots and matrix vegetation: Two African case studies. *Biotropica*, *46*(4), 387-394.

Arsenault, R., & Owen-Smith, N. (2002). Facilitation versus competition in grazing herbivore assemblages. *Oikos*, *97*(3), 313-318.

Association of Official Agricultural Chemists (AOAC). (1990). *Official methods of analysis* of the Association of Chemical Analytical Chemists (Helrich, K. (Ed.); 15th ed.). Association of Analytical Chemists, Inc, Virginia, USA.

Augustine, D. J., & McNaughton, S. J. (1998). Ungulate effects on the functional species composition of plant communities: herbivore selectivity and plant tolerance. *The Journal of Wildlife Management*, *62*(4), 1165-1183.

Azevedo, F. C. C., Lester, V., Gorsuch, W., Lariviere, S., Wirsing, A. J., & Murray, D. L. (2006). Dietary breadth and overlap among five sympatric prairie carnivores. *Journal of Zoology*, *269*(1), 127-135.

Bagchi, S., Goyal, S. P., & Sankar, K. (2003). Niche relationships of an ungulate assemblage in a dry tropical forest. *Journal of Mammalogy*, *84*(3), 981-988.

Bailey, D. W., & Provenza, F. D. (2008). Mechanisms determining large-herbivore distribution. In Prins, H. H. T. & Van Langevelde, F. (Eds.). *Resource Ecology, volume 23,* (pp. 7-28). Springer, Dordrecht.

Bakker, E. S., Ritchie, M. E., Olff, H., Milchunas, D. G., & Knops, J. M. (2006). Herbivore impact on grassland plant diversity depends on habitat productivity and herbivore size. *Ecology Letters*, *9*(7), 780-788.

Banerjee, G. (2001). *Habitat Use by the Great Indian Rhinoceros (Rhinoceros Unicornis) and Other Sympatric Large Herbivores in Kaziranga National Park, Assam, India*. Master's dissertation, Wildlife Institute of India, Dehradun.

Barton, K., & Barton, M. K. (2019). *Package 'MuMIn'*. R package Version, 1.

Baskaran, N., Balasubramanian, M., Swaminathan, S., & Desai, A. A. (2010). Feeding ecology of the Asian elephant *Elephas maximus* Linnaeus in the Nilgiri Biosphere Reserve, Southern India. *Journal of the Bombay Natural History Society*, *107*(1), 3-13.

Bawri, M., & Saikia, P. K. (2014). Preliminary study on the food plant species of Endangered Asiatic Wild Water Buffalo *Bubalus arnee* Kerr. in Kaziranga National Park, Assam, India. *NeBIO*, *5*(1), 49-55.

Bell, R. H. (1970). The use of the herb layer by grazing ungulates in the Serengeti. In Watson, A. (Eds.). *Animal populations in relation to their food resources* (pp. 111-124). Blackwell Science.

Bell, R. H. (1971). A grazing ecosystem in the Serengeti. *Scientific American*, *225*(1), 86-93.

Belovsky, G. E. (1997). Optimal foraging and community structure: the allometry of herbivore food selection and competition. *Evolutionary Ecology*, *11*(6), 641-672.

Bentley, A. (1978). *An introduction to the deer of Australia*. Koetong Trust Service, Victoria, Australia.

Bhatt, Y. D., Rawat, Y. S., & Singh, S. P. (1994). Changes in ecosystem functioning after replacement of forest by *Lantana* Shrubland in Kumaun Himalaya. *Journal of Vegetation Science*, *5*(1), 67–70.

Bhatta, R. (2011). Ecology and Conservation of Great Indian One horned Rhino (*Rhinoceros unicornis)* in Pobitora Wildlife Sanctuary Assam India. *Guwahati University*.

Bhattacharya, A. (1994). Rhinos of Jaldapara; Some problems for survival and their proposed conservation measures. *Zoo's Print, 9*(11), 5-6.

Bhattacharya, T., Kittur, S., Sathyakumar, S., & Rawat, G. S. (2012). Diet overlap between wild ungulates and domestic livestock in the Greater Himalaya: Implications for management of grazing practices. *Proceedings of the Zoological Society, 65*, 11-21.

Biswas, T. (2004). Hog Deer (*Axis porcinus* Zimmerman, 1780). In Sankar, K., & Goyal, S. P. (Eds.). *Ungulates of India, ENVIS Bulletin: Wildlife & Protected Areas, Volume- 07*, (pp. 61-78). Wildlife Institute of India, Dehra Dun.

Bizzarro, J. J., Yoklavich, M. M., & Wakefield, W. W. (2017). Diet composition and foraging ecology of US Pacific Coast groundfishes with applications for fisheries management. *Environmental Biology of Fishes*, *100*(4), 375-393.

Blankenship, L. H., & Field, C. R. (1972). Factors affecting the distribution of wild ungulates on a ranch in Kenya. Preliminary report. *African Zoology*, *7*(1), 281-302.

Bonal, B. S. (1998). *Status of swamp deer in Kaziranga National Park*. Forest Department, Assam.

Borah, J., & Deka, K. (2008). Nutritional evaluation of forage preferred by wild elephants in the Rani Range Forest, Assam, India. *Journal Gajaha*, *28*(2008), 41-43.

Borah, S. B., Sivasankar, T., Ramya, M. N. S. & Raju, P. L. N. (2018). Flood inundation mapping and monitoring in Kaziranga National Park, Assam using Sentinel-1 SAR data. *Environmental Monitoring and Assessment, 190*(9), 1-11.

Brahmachary, R. L., Rakshit, B. & Mallik, B. (1974). Further attempts to determine the food habits of the Indian Rhinoceros at Kaziranga. *Journal of the Bombay Natural History Society, 71*, 295–299.

Brauner, N., & Shacham, M. (1998). Role of range and precision of the independent variable in regression of data. *AIChE Journal, 44* (3), 603-611.

Brodeur, R. D., Smith, B. E., McBride, R. S., Heintz, R., & Farley, E. (2017). New perspectives on the feeding ecology and trophic dynamics of fishes. *Environmental Biology of Fishes*, *100*(4), 293-297.

Byers, C. R., Steinhorst, R. K., & Krausman, P. R. (1984). Clarification of a technique for analysis of utilization-availability data. *The Journal of Wildlife Management, 48*(3), 1050-1053.

Caughley, G., Peek, J. M., & Flader, S. L. (1981). Comments on *Natural Regulation of Ungulates (What Constitutes a Real Wilderness?)*. *Wildlife Society Bulletin (1973-2006)*, *9*(3), 232-238.

Champion, H. G., & Seth, S. K. (1968). *A Revised Survey of the Forest Types of India*. Manager of Publications. Government of India.

Chandra, K., Kosygin, L., Raghunathan, C., & Gupta, D. (2021). *Faunal Diversity of Biogeographic Zones of India: North-East*. Zoological Survey of India, Kolkata. 720pp.

Chase, J. M. (1996). Abiotic controls of trophic cascades in a simple grassland food chain. *Oikos*, *77*(3), 495-506.

Chaturvedi R. K. & Sankar K. (2006). *Laboratory manual for the physico-chemical analysis of soil, water and plant.* Wildlife Institute of India, Dehradun. 97pp.

Chen, J., Deng, X., Zhang, L., & Bai, Z. (2006). Diet composition and foraging ecology of Asian elephants in Shangyong, Xishuangbanna, China. *Acta Ecologica Sinica*, *26*(2), 309-316.

Chetri, M. (2006). Diet Analysis of Gaur (*Bos gaurus gaurus* Smith, 1827) by Micro-Histological Analysis of Fecal Samples in Parsa wildlife reserve, Nepal. *Our Nature*, *4*(1), 20-28.

Chillo, V., Rodríguez, D., & Ojeda, R. A. (2010). Niche partitioning and coexistence between two mammalian herbivores in the Dry Chaco of Argentina. *Acta Oecologica*, *36*(6), 611-616.

Choudhury, A. (1987). Railway threat to Kaziranga. *Oryx*, *21*(3), 160–163.

Choudhury, A. (1994). The decline of the wild water buffalo in North-east India. *Oryx*, *28*(1), 70-73.

Choudhury, A. (2010). *The Vanishing Herds: The Wild Water Buffalo*. Gibbon Books and Rhino Foundation for Nature in Northeast India.

Clarke, K. R. (1993). Non-parametric multivariate analyses of changes in community structure. *Australian Journal of Ecology*, *18*(1), 117-143.

Clauss, M., Steuer, P., Müller, D. W., Codron, D., & Hummel, J. (2013). Herbivory and body size: allometries of diet quality and gastrointestinal physiology, and implications for herbivore ecology and dinosaur gigantism. *PLoS One, 8*(10), e68714.

Codron, D., Lee-Thorp, J. A., Sponheimer, M., & Codron, J. (2007). Nutritional content of savanna plant foods: implications for browser/grazer models of ungulate diversification. *European Journal of Wildlife Research*, *53*(2), 100-111.

Colwell, R. K., & Elsensohn, J. E. (2014). EstimateS turns 20: Statistical estimation of species richness and shared species from samples, with non-parametric extrapolation. *Ecography*, *37*(6), 609-613.

Colwell, R. K., Chao, A., Gotelli, N. J., Lin, S. Y., Mao, C. X., Chazdon, R. L., & Longino, J. T. (2012). Models and estimators linking individual-based and sample-based rarefaction, extrapolation and comparison of assemblages. *Journal of Plant Ecology*, *5*(1), 3-21.

Crawley, M. J. (1989). The relative importance of vertebrate and invertebrate herbivores in plant population dynamics. In Bernays, E. A. (Eds.). *Insect-plant interactions* (pp. 45-71). CRC Press, New York.

Cupples, J. B., Crowther, M. S., Story, G., & Letnic, M. (2011). Dietary overlap and prey selectivity among sympatric carnivores: Could dingoes suppress foxes through competition for prey?. *Journal of Mammalogy*, *92*(3), 590-600.

Datye, H. S. (1995). Ecology of elephants of Dalma Wildlife Sanctuary, Bihar, Central India. In *Ecology of the Asian Elephant. Final Report (1978-1992)*. Bombay Natural History Society, Bombay, India.

Davidson, D. W. (1993). The effects of herbivory and granivory on terrestrial plant succession. *Oikos*, *68*(1), 23-35.

De Barba, M., Waits, L.P., Genovesi, P., Randi, E., Chirichella, R., & Cetto, E. (2010). Comparing opportunistic and systematic sampling methods for non-invasive genetic monitoring of a small translocated brown bear population. *Journal of Applied Ecology*, *47*(1), 172–181.

De Souza Portella, A., & Vieira, E. M. (2016). Diet and trophic niche breadth of the rare acrobatic cavy *Kerodon acrobata* (Rodentia: Caviidae) in a seasonal environment. *Mammal Research*, *61*(3), 279-287.

Demment, M. W., & Van Soest, P. J. (1985). A nutritional explanation for body-size patterns of ruminant and nonruminant herbivores. *The American Naturalist*, *125*(5), 641-672.

Desai, A. A. (2001). *Nature's Masterpiece: The Elephant*. Karnataka Forest Department, Bangalore, India. 48pp.

Devi, A., Hussain, S. A., Sharma, M., & Badola, R. (2022b). Biological invasion by livestock and dogs in wet grasslands of Brahmaputra floodplains of Assam affecting its integrity. *Asian Grassland Conference*, 19-21 April 2022, 25.

Devi, A., Hussain, S. A., Sharma, M., Gopi, G. V., & Badola, R. (2022a). Seasonal pattern of food habits of large herbivores in riverine alluvial grasslands of Brahmaputra floodplains, Assam. *Scientific reports*, *12*(1), 1-15.

Dhungel, S. K., & O’Gara, B. W. (1991). Ecology of the Hog Deer in Royal Chitwan National Park, Nepal. *Wildlife Monographs*, 3-40.

Dinerstein, E. (1979). An ecological survey of the Royal Karnali-Bardia Wildlife Reserve, Nepal. Part II: Habitat/animal interactions. *Biological Conservation*, *16*(4), 265-300.

Dinerstein, E. (1980). An ecological survey of the Royal Karnali-Bardia Wildlife Reserve, Nepal: Part III: Ungulate populations. *Biological Conservation*, *18*(1), 5-37.

Dinerstein, E. (2003). *The Return of the Unicorns: The Natural History and Conservation of the Greater One-Horned Rhinoceros*. Columbia University Press, New York. 384pp.

Dinerstein, E. (2015). Greater one-horned rhinoceros, *Rhinoceros unicornis*: pp. 95-111. In Johnsingh, A. J. T. & Majrekar, N. (Eds.) *Mammals of South Asia Volume II* (pp. 95-111). Universities Press (India) Private Limited.

Dinerstein, E., & Price, L. (1991). Demography and Habitat Use by Greater One-Horned Rhinoceros in Nepal. *The Journal of Wildlife Management*, *55*(3), 401-411.

Dormann, C. F., Gruber, B., & Fründ, J. (2008). Introducing the Bipartite Package: Analysing Ecological Networks. *Interaction*, *8*(2), 8-11.

Duncan, A. J., & Poppi, D. P. (2008). Nutritional ecology of grazing and browsing ruminants. In Gordon, I. J., & Prins, H. H. (Eds.). *The Ecology of Browsing and Grazing* (pp. 89-116). Springer Berlin, Heidelberg.

Durso, A. M., Willson, J. D., & Winne, C. T. (2013). Habitat influences diet overlap in aquatic snake assemblages. *Journal of Zoology*, *291*(3), 185-193.

Dutta, D. K., Bora, P. J., Mahanta, R., Sharma, A., & Swargowari, A. (2016). Seasonal variations in food plant preferences of reintroduced Rhinos *Rhinoceros unicornis* (Mammalia: Perrissodactyla: Rhinocerotidae) in Manas National Park, Assam, India. *Journal of Threatened Taxa*, *8*(13), 9525-9536.

Edwards, G. R., & Crawley, M. J. (1999). Herbivores, seed banks and seedling recruitment in mesic grassland. *Journal of Ecology*, *87*(3), 423-435.

Eisenberg, J. F., & Lockhart, M. (1972). *An ecological reconnaissance of Wilpattu National Park, Culon.* Smithsonian Institution Press, Washington, D.C.

Ellerman, J. R., & Morrison-Scott, T. C. S. (1951). *"Checklist of Palaearctic and Indian Mammals 1758 to 1946".* British Museum (Natural History), Tonbridge Printers, London.

Fernando, P., Vidya, T. N. C., Payne, J., Stuewe, M., Davison, G., Alfred, R. J., Andau, P., Bosi, E., Kilbourn, A., & Melnick, D. J. (2003). DNA analysis indicates that Asian elephants are native to Borneo and are therefore a high priority for conservation. *PLoS Biology*, *1*(1), e6.

Field, C. R., & Laws, R. M. (1970). The distribution of the larger herbivores in the Queen Elizabeth National Park, Uganda. *Journal of Applied Ecology*, *7*(2), 273-294.

Foose, T. J., & Van Strien, N. (1997). *Asian Rhinos - Status Survey and Conservation Action Plan.* IUCN/SSC Asian Rhino Specialist Group. 112pp.

Freeland, W. J. & Janzen, D. H. (1974). Strategies in herbivory by mammals: The role of plant secondary compounds. *The American Naturalist*, *108*, 269-289.

Fryxell, J. M., Wilmshurst, J. F., Sinclair, A. R. E., Haydon, D. T., Holt, R. D., & Abrams, P. A. (2005). Landscape scale, heterogeneity, and the viability of Serengeti grazers. *Ecology Letters, 8,* 328–335.

Gee, E. P. (1952). The Great Indian One-Horned Rhinoceros. *Oryx*, *1*(5), 224–227.

Geethanjali, M. (2017). Ecosystem goods and services provided by 'beels' in Kaziranga. *Indian Forester*, *143*(12), 1249-1254.

Geist, V. (1974). On the relationship of social evolution and ecology in ungulates. *American Zoologist*, *14*(1), 205-220.

Gentry, A. W. (1992). The subfamilies and tribes of the family Bovidae. *Mammal Review*, *22*(1), 1-32.

Gentry, A., Clutton-Brock, J., & Groves, C. P. (2004). The naming of wild animal species and their domestic derivatives. *Journal of Archaeological Science*, *31*(5), 645-651.

Goering, H. K., & Van Soest, P. J. (1970). *Forage Fiber Analyses (Apparatus, reagents, procedures, and some applications)*. US Agricultural Research Service, Washington, D. C. 20pp.

Gordon, I. J. (2003). Browsing and grazing ruminants: are they different beasts. *Forest Ecology and Management*, *181*(1-2), 13-21.

Gordon, I. J., & Illius, A. W. (1996). The nutritional ecology of African ruminants: A reinterpretation. *Journal of Animal Ecology*, *65*(1), 18-28.

Gotelli, N. J., & Graves, G. R. (1996). *Null Models in Ecology*. Smithsonian Institution Press, Washington, D. C. 368pp.

Green, M. J. (1987). Ecological separation in Himalayan ungulates. *Journal of Zoology*, *1*(4), 693-719.

Groves, C. P. (1996). The taxonomy of the Asian wild buffalo from the Asian mainland. *Zeitschrift fuer Saeugetierkunde (Germany)*, *61*(6), 327-338.

Grubb, P. (1990). List of deer species and subspecies. *The Journal of British Deer Society*, *8*(3), 153-155.

Grzimek, M., & Grzimek, B. (1960). Census of Plains Animals in the Serengeti National Park, Tanganyika. *The Journal of Wildlife Management*, *24*(1), 27-37.

Gupta, S. K., Kumar, A., Angom, S., Singh, B., Ghazi, M. G. U., Tuboi, C., & Hussain, S. A. (2018). Genetic analysis of endangered hog deer (*Axis porcinus*) reveals two distinct lineages from the Indian subcontinent. *Scientific reports*, *8*(1), 1-12.

Gwynne, M. D., & Bell, R. H. V. (1968). Selection of vegetation components by grazing ungulates in the Serengeti National Park. *Nature*, *220*(5165), 390-393.

Gyawali, S. R. (1986). *Diet analysis of greater one-horned rhinoceros by fecal analysis*. Doctoral Thesis, Tribhuvan University, Kathmandu, Nepal.

Hajra, P. K. & Jain, S. K. (1994). *Botany of Kaziranga and Manas.* Surya International Publications. 301pp.

Hajra, P. K. (1978). *Flora of Kaziranga National Park and Manas Wild Life Sanctuary of Assam*. Doctoral Thesis, Gauhati University.

Hardin, G. (1960). The Competitive Exclusion Principle: An idea that took a century to be born has implications in ecology, economics, and genetics. *Science*, *131*(3409), 1292-1297.

Harikumar, G., Thomas, B., Joseph, K. J., & Zacharias, V. J. (1999). Population Dynamics of Sambar *Cervus unicolor,* in Periyar Tiger Reserve. *Indian Forester*, *125*(10), 995-1003.

Harrell, J. R., Frank, E., Harrell, J. R., & Maintainer, F. E. (2019). Package 'Hmisc'. CRAN2018, 2019, 235-236.

Hartvigsen, G., & McNaughton, S. J. (1995). Tradeoff between height and relative growth rate in a dominant grass from the Serengeti ecosystem. *Oecologia*, *102*(3), 273-276.

Hazarika, B. C., & Saikia, P. K. (2012). Food habit and feeding patterns of Great Indian One-horned Rhinoceros (*Rhinoceros unicornis*) in Rajiv Gandhi Orang National Park, Assam, India. *International Scholarly Research Network Zoology*, *2012*, 1-11.

Hirst, S. M. (1975). Ungulate-habitat relationships in a South African woodland/savanna ecosystem. *Wildlife Monographs*, 44, 3-60.

Hofmann, R. R. (1973). The Ruminant Stomach: Stomach Structure and Feeding Habits of East African Game Ruminants. *East African Monographs in Biology*, *2*, 1-364.

Hofmann, R. R. (1989). Evolutionary steps of ecophysiological adaptation and diversification of ruminants: a comparative view of their digestive system. *Oecologia*, *78*(4), 443-457.

Hofmann, R. R., & Stewart, D. R. M. (1972). Grazer or browser: a classification based on the stomach-structure and feeding habits of East African ruminants. *Mammalia, 36*(2), 226-240.

Holechek, J. L., Vavra, M., & Pieper, R. D. (1982). Botanical Composition Determination of Range Herbivore Diets: A Review. *Journal of Range Management*, *35*(3), 309–315.

Hopkins, A. (2000). Herbage production. In Hopkins, A. (Eds.). *Grass, Its production and utilization* (pp. 90-110). Blackwell Science, USA.

Hutchins, M., Kleiman, D. G., Geist, V., & McDade, M. C. (2004). *Grzimek's Animal Life Encyclopedia*, *Volume (15 & 16),* Mammals IV & V. Gale Group, Detroit, USA.

Hutchinson, G. E. (1957). Concluding remarks Cold Spring Harbor Symposia on Quantitative Biology. *Gs Search*, *22*, 415–427.

Ickes, K., DeWalt, S. J., & Appanah, S. (2001). Effects of native pigs (Sus scrofa) on woody understorey vegetation in a Malaysian lowland rain forest. *Journal of Tropical Ecology*, *17*(2), 191-206.

IUCN (2022). The IUCN Red List of Threatened Species. Available online at https://www.iucnredlist.org.

Jachmann, H. & Bell, R. H. V. (1984). The use of elephant droppings in assessing numbers, occupance and age structure: A refinement of the method. *African Journal of Ecology*, *22*(2), 127–141.

Jacobs, J. (1974). Quantitative measurement of food selection. *Oecologia, 14*(4), 413-417.

Jain, S. K. & Hajra, P. K. (1975). On the botany of Manas Wild Life Sanctuary in Assam. *The Bulletin of the Botanical Survey of India, 17*(1-4), 75–86.

Janis, C. M., & Ehrhardt, D. (1988). Correlation of relative muzzle width and relative incisor width with dietary preference in ungulates. *Zoological Journal of the Linnean Society*, *92*(3), 267-284.

Jarman, P. (1974). The social organisation of antelope in relation to their ecology. *Behaviour*, *48*(1-4), 215-267.

Jathanna, D., Karanth, K. U., & Johnsingh A. J. T. (2003). Estimation of large herbivore densities in the tropical forests of Southern India using distance sampling. *Journal of Zoology, 261*(3), 285–290.

Jayson, E. A. (1999). Habitat preference of five herbivores in the Chimmony Wildlife Sanctuary. *Indian Forester, 125*(10), 975-985.

Jnawali, S. R. (1995). *Population ecology of greater one-horned rhinoceros (Rhinoceros unicornis) with particular emphasis on habitat preference, food ecology and ranging behavior of a reintroduced population in Royal Bardia National Park in lowland Nepal*. Doctoral Thesis, Agricultural University of Norway.

Johnsingh, A. J. T. & Manjrekar, N. (2015). *Mammals of South Asia, Volume II*. Universities Press (India) Private Limited. 799pp.

Johnsingh, A. J. T. & Nameer, P. O. (2015). Introduction. In Johnsingh, A. J. T. & Majrekar, N. (Eds.). *Mammals of South Asia Volume II* (pp. xxxiii-lxiv). Universities Press (India) Private Limited.

Johnsingh, A. J. T., & Sankar, K. (1991). Food plants of chital, sambar and cattle on Mundanthurai Plateau, Tamil Nadu, South India. *Mammalia, 55*, 57-66.

Johnsingh, A. J. T., Ramesh, K., Qureshi, Q., David, A., Goyal, S. P., Rawat, G. S., Rajapandian, K., & Prasad, S. (2004). *Conservation Status of Tiger and Associated Species in the Terai Arc Landscape, India*. Wildlife Institute of India, Dehradun.

Johnsingh, A. J. T., William, C. A., & Desai, A. A. (2015). Introduction. In Johnsingh, A. J. T. & Majrekar, N. (Eds.). *Mammals of South Asia Volume II* (pp. 71-94). Universities Press (India) Private Limited.

Johnson, M. K., Wofford, H. H. & Pearson, H. A. (1983). *Microhistological Techniques for Food Habits Analyses.* U.S. Department of Agriculture. 40pp.

Jones, M. E., & Barmuta, L. A. (1998). Diet overlap and relative abundance of sympatric dasyurid carnivores: A hypothesis of competition. *Journal of Animal Ecology*, *67*(3), 410-421.

Karanth, K. K., Curran, L. M., & Reuning-Scherer, J. D. (2006). Village size and forest disturbance in Bhadra Wildlife Sanctuary, Western Ghats, India. *Biological Conservation*, *128*(2), 147-157.

Kar-Gupta, K., & Kumar, A. (1994). Leaf chemistry and food selection by common langurs (*Presbytis entellus*) in Rajaji National Park, Uttar Pradesh, India. *International Journal of Primatology*, *15*(1), 75-93.

Kartzinel, T. R., Chen, P. A., Coverdale, T. C., Erickson, D. L., Kress, W. J., Kuzmina, M. L., Rubenstein, D. I., Wang, W., & Pringle, R. M. (2015). DNA metabarcoding illuminates dietary niche partitioning by African large herbivores. *Proceedings of the National Academy of Sciences*, *112*(26), 8019-8024.

Kelton, S. D., & Skipworth, J. P. (1987). Food of sambar deer (*Cervus unicolor*) in a Manawatu (New Zealand) flax swamp. *New Zealand Journal of Ecology*, *10*, 149-152.

Khan, J.A. & Johnsingh, A. J. T. (2015). Sambar (*Rusa unicolor*). In Johnsingh, A. J. T. & Majrekar, N. (Eds.). *Mammals of South Asia*, *Volume-II* (pp. 223-241). Universities Press (India) Private Limited.

Kittur, S., Sathyakumar, S., & Rawat, G. S. (2007). *Himalayan tahr, livestock interaction in Kedarnath wildlife sanctuary, Uttaranchal.* Final Report. Wildlife Institute of India, Dehradun.

Kleiber, M. (1932). *The fire of life. An introduction to animal energetics*. Krieger, USA.

Klein, D. R. (1970). Food selection by North American deer and their response to over-utilization of preferred plant species. *Animal Populations in Relation to their Food Resources*, 25-46.

Kleynhans, E. J., Jolles, A. E., Bos, M. R., & Olff, H. (2011). Resource partitioning along multiple niche dimensions in differently sized African savanna grazers. *Oikos*, *120*(4), 591-600.

Koirala, R. K., Raubenheimer, D., Aryal, A., Pathak, M. L., & Ji, W. (2016). Feeding preferences of the Asian elephant (*Elephas maximus*) in Nepal. *BMC ecology*, *16*(1), 54.

Konwar, P., Saikia, M. K., & Saikia, P. K. (2009). Abundance of food plant species and food habits of *Rhinoceros unicornis* Linn. in Pobitora Wildlife Sanctuary, Assam, India. *Journal of Threatened Taxa*, *1*(9), 457-460.

Krebs, C. J. (1999). *Ecological Methodology* (2nd ed.). Addison Welsey Educational Publishers Inc. 620pp.

Kumara, H. N. & Singh, M. (2004). The influence of differing hunting practices on the relative abundance of mammals in two rainforest areas of the Western Ghats, India. *Oryx, 38*(3), 321–327.

Kushwaha, S. P. S. (1997). Environmental monitoring and cyclone impact assessment on Sriharikota Island, India. *Geocarto International*, *12*(2), 55-62.

Kushwaha, S. P. S. (2008). Mapping of Kaziranga Conservation Area, Assam. *Indian Institute of Remote Sensing, Dehra Dun, India*.

Kushwaha, S. P. S., & Unni, N. V. M. (1986). Application of Remote Sensing techniques in forest cover monitoring and habitat evaluation. A case study in Kaziranga National Park, Assam. In *Proceedings of seminar-cum-workshop on wildlife habitat evaluation using remote sensing techniques* (pp. 238-247). Indian Institute of Remote Sensing/Wildlife Institute of India, Dehradun.

Kutner, M. H., Nachtsheim, C. J., Neter, J., & Li, W. (2005). *Applied Linear Statistical Models* (5th ed.). McGraw-Hill Irwin, Boston. 1396pp.

Lahan, P., & Sonowal, R. (1973). Kaziranga wildlife sanctuary, Assam. *Journal of the Bombay Natural History Society*, *70*(2), 245–278.

Lamprey, H. F. (1963). Ecological separation of the large mammal species in the Tarangire Game Reserve, Tanganyika. *African Journal of Ecology, 1*(1), 63-92.

Lamprey, R. H., & Reid, R. S. (2004). Expansion of human settlement in Kenya's Maasai Mara: What future for pastoralism and wildlife?. *Journal of Biogeography*, *31*(6), 997-1032.

Laurie, A. (1982). Behavioural ecology of the Greater one-horned rhinoceros (*Rhinoceros unicornis*). *Journal of Zoology*, *196*(3), 307-341.

Laurie, W. A. (1978). *The ecology and behaviour of the greater one-horned rhinoceros.* Doctoral Thesis, University of Cambridge.

Legendre, P. & Legendre, L. F. J. (1998). *Numerical Ecology* (2nd ed.). Elsevier Science, Amsterdam. 852pp.

Leslie Jr, D. M. (2011). Rusa unicolor (Artiodactyla: Cervidae). *Mammalian Species*, *43*(871), 1-30.

Lubchenco, J. (1978). Plant species diversity in a marine intertidal community: importance of herbivore food preference and algal competitive abilities. *The American Naturalist*, *112*(983), 23-39.

Lynam, A. J., Round, P. D., & Brockelman, W. Y. (2006). *Status of Birds and Large Mammals in Thailand's Dong Phayayen - Khao Yai Forest Complex*. Biodiversity Research and Training (BRT) Program and Wildlife Conservation Society, Bangkok. 245pp.

Mabragana, E., & Giberto, D. A. (2007). Feeding ecology and abundance of two sympatric skates, the shortfin sand skate *Psammobatis normani* McEachran, and the smallthorn sand skate *P. rudis* Günther (Chondrichthyes, Rajidae), in the Southwest Atlantic. *ICES Journal of Marine Science*, *64*(5), 1017-1027.

MacArthur, R., & Levins, R. (1967). The limiting similarity, convergence, and divergence of coexisting species. *The American Naturalist*, *101*(921), 377-385.

Manjrekar, M. P. (2015). *Behavioural Patterns and Food Habits of Re-Introduced Gaur (Bos Gaurus Gaurus) in Bandhavgarh Tiger Reserve Madhya Pradesh.* Doctoral Thesis, Saurashtra University.

Marquis, R. J. (2010). The role of herbivores in terrestrial trophic cascades. In Terborgh, J. & Estes, J. A. (Eds.). *Trophic Cascades: Predators, Prey, and the Changing Dynamics of Nature* (pp. 109-123). Island Press, Washington, DC.

Martin, C. (1977). Status and ecology of the Barasingha *(Cervus duvauceli brander)* in Kanha National Park (India). *Journal of the Bombay Natural History Society*, *74*(1), 60-132.

Martin, C. (1982). Interspecific relationship between barasingha and axis deer in Kanha MP, India and relevance to management. In Wemmer, C. W. (Eds.). *Biology and management of the Cervidae* (pp. 299–306). Smithsonian Institution Press, Washington, DC.

Martin, C., & Gopal, R. (2015). Barasingha (Indian swamp deer) *Rucervus duvaucelii*. In Johnsingh, A. J. T. & Majrekar, N. (Eds.). *Mammals of South Asia Volume II* (pp. 242-257). Universities Press (India) Private Limited.

Maynard, L. A., & Loosli, J. K. (1969). *Animal Nutrition* (6^{th} ed.). 613pp.

McDowell, L. R. (1985). Nutrient requirements of ruminants. In McDowell, L. R. (Eds.). *Nutrition of grazing ruminants in warm climates* (pp. 21-36). Academic Press, New York.

McKay, G. M. (1973). Behavior and ecology of the Asiatic elephant in Southeastern Ceylon. *Smithsonian Contributions to Zoology*, *125*, 1-113.

McNaughton, S. J., & Georgiadis, N. J. (1986). Ecology of African grazing and browsing mammals. *Annual Review of Ecology and Systematics*, *17*, 39-65.

McNaughton, S. J., Zuniga, G., McNaughton, M. M., & Banyikwa, F. F. (1997). Ecosystem catalysis: soil urease activity and grazing in the Serengeti ecosystem. *Oikos*, *80*(3), 467-469.

Menon, V. (2014). *Indian Mammals: A field guide*. Hachette India.

Milchunas, D. G., & Lauenroth, W. K. (1993). Quantitative effects of grazing on vegetation and soils over a global range of environments. *Ecological monographs*, *63*(4), 327-366.

Miller, R. (1975). Notes on the behaviour of hog deer in an enclosure. *Natural History Bulletin of the Siam Society*, *26*, 105-131.

Minson, D. J. (1976). *Carbohydrate research in plants and animals. Miscellaneous Papers 12*. Landbouwhoges school, Wageningen, Netherlands. 101-114pp.

Mishra R.P. & A. Gaur. (2019). *Conservation status of Asiatic Wild Buffalo (Bubalus arnee) in Chhattisgarh revealed through genetic study.* Technical Report of Wildlife Trust of India and CSIR-CCMB. 17pp.

Mishra, R. P. (2001). *Studies on Indian wild buffalo (Bubalus bubalis L.) and it's habitat in Udanti Wildlife Sanctuary*. Doctoral Thesis, Pt. Ravishankar Shukla University, Raipur, Chhattisgarh, India.

Moen, A. N. (1978). Seasonal changes in heart rates, activity, metabolism, and forage intake of white-tailed deer. *The Journal of Wildlife Management*, *42*(4), 715-738.

Moore, G. (2015). Hog Deer (*Axis porcinus*). In Johnsingh, A. J. T. & Majrekar, N. (Eds.). *Mammals of South Asia Volume II* (pp. 272-286). Universities Press (India) Private Limited.

Muley, P.D. (2001). *Genetic and Morphometric Studies to Differentiate Between Wild and Domestic Asian Water Buffaloes (Bubalus bubalis) and their Hybirds in Kaziranga National Park, Assam, India.* Doctoral Thesis, The University of Wisconsin-Madison.

Murali, K. S., & Setty, R. S. (2001). Effect of weeds *Lantana camara* and *Chromelina odorata* growth on the species diversity, regeneration and stem density of tree and shrub layer in BRT sanctuary. *Current Science*, *80*(5), 675-678.

Mysterud, A. (2000). The relationship between ecological segregation and sexual body size dimorphism in large herbivores. *Oecologia, 124*(1), 40-54.

Nameer, P. O. (2000). *Checklist of Indian mammals.* Kerala State Forest Department and Kerala Agricultural University. 90 + XXVpp.

Nelson, J. R., & Leege, T. A. (1982). Nutritional requirements and food habits. *Elk of North America: ecology and management*, 323.

Neu, C. W., Byers, C. R., & Peek, J. M. (1974). A technique for analysis of utilization-availability data. *The Journal of Wildlife Management, 38*(3), 541-545.

Ngampongsai, C. (1987). *Habitat use by the sambar (Cervus unicolor) in Thailand: A case study for Khao-Yai National Park. Biology and management of the Cervidae.* Smithsonian Institution Press, Washington, D.C. 289–298pp.

Nowak, R. M. (1999). *Walker's Mammals of the World, Volume I,* (6th ed.). The Johns Hopkins University Press, Baltimore, Maryland. 836pp.

Odum, E. P. (1971). *Fundamentals of ecology* (3rd ed.). Saunders.

Oksanen, J., Blanchet, F. G., Kindt, R., Legendre, P. R., O'Hara, B., Simpson, G. L., Solymos, P., Stevans, H., & Wagner, H. H. (2011). *Vegan: Community Ecology Package.* R package version. 117–118pp.

Olff, H., Ritchie, M. E. & Prins, H. H. T. (2002). Global environmental controls of diversity in large herbivores. *Nature, 415,* 901–904.

Olivier, R. (1978). Distribution and status of the Asian elephant. *Oryx*, *14*(4), 379-424.

Owen-Smith, R. N. (1988). *Megaherbivores: The Influence of Very Large Body Size on Ecology*. Cambridge University Press. 364pp.

Owen-Smith, R. N. (2002). *Adaptive Herbivore Ecology: From Resources to Populations in Variable Environments*. Cambridge University Press.

Padmalal, U. K. G. K., Takatsuki, S., & Jayasekara, P. (2003). Food habits of sambar *Cervus unicolor* at the Horton Plains National Park, Sri Lanka. *Ecological Research*, *18* (6), 775-782.

Pansu, J., Guyton, J. A., Potter, A. B., Atkins, J. L., Daskin, J. H., Wursten, B., Kartzinel, T.R., & Pringle, R. M. (2019). Trophic ecology of large herbivores in a reassembling African ecosystem. *Journal of Ecology*, *107*(3), 1355-1376.

Parikh, G. L., Forbey, J. S., Robb, B., Peterson, R. O., Vucetich, L. M., & Vucetich, J. A. (2017). The influence of plant defensive chemicals, diet composition, and winter severity on the nutritional condition of a free-ranging, generalist herbivore. *Oikos*, *126*(2), 1–8.

Patar, K. C. (1977). Food preferences of the one horned Indian rhinoceros (*Rhinoceros unicornis)*. *Kaziranga National Park, India: Michigan State University*. Department of Fisheries and Wildlife.

Patar, K. C. (2005). *Behavioural Patterns of The One Horned Indian Rhinoceros Illustrated*. Spectrum Publications.

Pathak, B. N. (1978). *Kaziranga National Park-1978 Census Report*. Government of Assam, Department of Forest.

Payne, K. B., Langbauer, W. R., & Thomas, E. M. (1986). Infrasonic calls of the Asian elephant (*Elephas maximus*). *Behavioral Ecology and Sociobiology*, *18*(4), 297-301.

Pianka, E. R. (1969). Sympatry of desert lizards (Ctenotus) in Western Australia. *Ecology*, *50*(6), 1012-1030.

Pianka, E. R. (1973). The Structure of Lizard Communities. *Annual Review of Ecology and Systematics, 4*(1), 53–74.

Pianka, E. R. (1974). Niche overlap and diffuse competition. *Proceedings of the National Academy of Sciences, 71*(5), 2141-2145.

Polley, H. W., & Collins, S. L. (1984). Relationships of vegetation and environment in buffalo wallows. *American Midland Naturalist*, 178-186.

Pradhan, N. M., Wegge, P., Moe, S. R., & Shrestha, A. K. (2008). Feeding ecology of two endangered sympatric megaherbivores: Asian elephant *Elephas maximus* and Greater one-horned rhinoceros *Rhinoceros unicornis* in lowland Nepal. *Wildlife Biology*, *14*(1), 147-154.

Prater, S. H. (1971). *The Book of Indian Animals* (3rd ed.). Bombay Natural History Society, Bombay. 324pp.

Prater, S. H. (1985). *The Book of Indian Animals* (2nd ed.). Bombay Natural History Society. 323pp.

Pringle, R. M. (2008). Elephants as agents of habitat creation for small vertebrates at the patch scale. *Ecology*, *89*(1), 26-33.

Prins, H. H. T. & Van Langevelde, F. (2008). Assembling a diet from different places. In Prins, H. H. T. & Van Langevelde, F. (Eds.). *Resource Ecology, volume 23*, (pp. 129–155). Springer, Dordrecht.

Prins, H. H. T. (1996). *Ecology and behaviour of the African buffalo: Social inequality and decision making.* Chapman & Hall Publishers, London. 293pp.

Prins, H. H., & Loth, P. E. (1988). Rainfall patterns as background to plant phenology in northern Tanzania. *Journal of Biogeography, 15*(3), 451-463.

Putman, R. J. (1988). *The Natural History of Deer*. Comstock Pub. Associates. 191pp.

Putman, R. J. (1996). Ungulates in temperate forest ecosystems: perspectives and recommendations for future research. *Forest Ecology and Management*, *88* (1-2), 205-214.

Quinn, G. P., & Keough, M. J. (2002). *Experimental Design and Data Analysis for Biologists*. Cambridge University Press, New York. 537pp.

Qureshi, Q., Sawarkar, V. B., & Mathur, P. K. (1995). *Ecology and Management of Swamp Deer (Cervus duvauceli) in Dhudhwa Tiger Reserve, U.P. India*. Project Report. Wildlife Institute of India, Dehradun.

Ripple, W. J., Newsome, T. M., Wolf, C., Dirzo, R., Everatt, K. T., Galetti, M., Hayward, M.W., Kerley, G.I.H., Levi, T., Lindsey, P.A., Macdonald, D.W., Malhi, Y., Painter, L.E., Sandom, C.J., Terborgh, J., & Van Valkenburgh, B. (2015). Collapse of the world's largest herbivores. *Science advances*, *1*(4), e1400103.

Robbins, C. (2012). *Wildlife Feeding and Nutrition*. Academic Press.

Rodgers, W. A., & Panwar, H. S. (1988). *Planning a Wildlife Protected Area Network in India. Volume 1*. Wildlife Institute of India, Dehradun. 341pp.

Rosenthal, G. A. & Janzen, D. H. (1979). *Herbivores: Their interaction with secondary plant metabolites.* Academic Press, New York. 468pp.

Sale, P. F. (1974). Overlap in resource use, and interspecific competition. *Oecologia*, *17*(3), 245-256.

Sankar, K. (1994). *The ecology of three large sympatric herbivores (chital, sambar, nilgai) with special reference for reserve management in Sariska Tiger Reserve, Rajasthan*. Doctoral Thesis, University of Rajasthan.

Sankar, K., Nigam, P., Navaneethan, B., & Manjrekar, M. P. (2015). *Monitoring Reintroduced Gaur (Bos gaurus gaurus) in Bandhavgarh Tiger Reserve, Madhya Pradesh*. Phase -I Final Report. Wildlife Institute of India, Chandrabani, Dehradun. 99pp.

Sankar, K., Pabla, H. S., Patil, C. K., Nigam, P., Quereshi, Q., Navaneethan, B., Manjreakar, M., Virkar, P. S., & Mondal, K. (2014). *Ranging Patterns and Habitat Use of Re-Introduced Gaur (Bos gaurus gaurus) in Bandhavgarh Tiger Reserve Madhya Pradesh.* Final Report. Wildlife Institute of India, Dehradun.

Sankar, K., & Acharya, B. (2004). Sambar (*Cervus unicolor* Kerr, 1792). In Sankar, K. & Goyal, S.P. (Eds.). *Ungulates of India*, *ENVIS Bulletin: Wildlife & Protected Areas, Volume- 07*. Wildlife Institute of India, Dehradun, India.

Sankaran, R. (1990). Status of the Swamp Deer (*Cervus duvauceli duvauceli*) in the Dudwa National Park, Uttar Pradesh, India. *Journal of the Bombay Natural History Society*, *87*(2), 250-259.

Santra, A. K., & Gendley, M. K. (2014). Availability and Utilization Pattern of Forage Plants in relation to their Nutritive Values by Wild Elephants in South West Forests. *Journal of Animal Research*, *4*(1), 29-34.

Sarkar, P., Verma, S., & Menon, V. (2012). Food selection by Asian elephant (*Elephus maximus*) in Kameng Elephant Reserve in Northeast India. *The Clarion-International Multidisciplinary Journal*, *1*(1), 70-79.

Sarma, J. N. (2005). Fluvial process and morphology of the Brahmaputra River in Assam, India. *Geomorphology*, *70*(3-4), 226-256.

Satkopan, S. (1972). Key to identification of plant remains in animal dropping. *Journal of the Bombay Natural History Society*, *69*(1), 139–150.

Schaller, G. B. (1967). *The Deer and the Tiger: Study of Wild Life in India*. University of Chicago Press. 370pp.

Schoener, T. W. (1970). Nonsynchronous spatial overlap of lizards in patchy habitats. *Ecology*, *51*(3), 408-418.

Schoener, T. W. (1974). Resource Partitioning in Ecological Communities: Research on how similar species divide resources helps reveal the natural regulation of species diversity. *Science*, *185*(4145), 27-39.

Scogings, P. F., Theron, G. K., & Bothma, J. D. P. (1990). Two quantitative methods of analysing ungulate habitat data. *South African Journal of Wildlife Research*, *20*(1), 9-13.

Semiadi, G., Barry, T. N., Muir, P. D., & Hodgson, J. (1995). Dietary preferences of sambar (*Cervus unicolor*) and red deer (*Cervus elaphus*) offered browse, forage legume and grass species. *The Journal of Agricultural Science*, *125*(1), 99-107.

Sharma, B., & Sarma, K. (2014). Status Identification and Prediction of Kaziranga-Karbi Anglong Wildlife Corridor of Assam, India, Using Geospatial Technology. *Journal of Landscape Ecology*, *7*(2), 45–58.

Shea, S. M., Flynn, L. B., Marchinton, R. L., & Lewis, J. C. (1990). Part II: Social behaviour, movement ecology, and food habits. In Flynn, L. B. (Ed.) *Ecology of sambar deer on St. Vincent National Wildlife Refuge, Florida*, *Volume- 25,* (pp. 13-62). Tall Timbers Research Station, Tallahassee, Florida.

Shrestha, R., Wegge, P., & Koirala, R. A. (2005). Summer diets of wild and domestic ungulates in Nepal Himalaya. *Journal of Zoology*, *266*(2), 111-119.

Shrestha, T. K., Hecker, L. J., Aryal, A., & Coogan, S. C. P. (2020). Feeding preferences and nutritional niche of wild water buffalo (*Bubalus arnee*) in Koshi Tappu Wildlife Reserve, Nepal. *Ecology and Evolution*, *10*(14), 6897-6905.

Sih, A., Crowley, P., McPeek, M., Petranka, J., & Strohmeier, K. (1985). Predation, competition, and prey communities: a review of field experiments. *Annual Review of Ecology and Systematics*, 269-311.

Sinclair, A. R. E. (1979). Dynamics of the Serengeti Ecosystem: Process and Pattern. In Sinclair, A. R. E., & Norton-Griffiths, M. (Eds.). *Serengeti: Dynamics of an Ecosystem* (pp. 1-30). The University of Chicago Press, Chicago.

Sinclair, A. R. E. (1995). Equilibria in plant-herbivore interactions. In Sinclair, A. R. E. & Arcese, P (Eds.). *Serengeti II: Dynamics, Management, and Conservation of an Ecosystem* (pp. 91-113). The University of Chicago Press, Chicago.

Sinclair, A. R. E. (2003). Mammal population regulation, keystone processes and ecosystem dynamics. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *358*(1438), 1729-1740.

Sivaganesan, N., & Johnsingh, A. J. T. (1995). Food resources crucial to the wild elephants in Mudumalai Wildlife Sanctuary, South India. In Daniel, J. C. & Datye, H. S. (Eds.). *A week with elephants: Proceedings of the International Seminar on the Conservation of Elephant, June 1993* (pp. 405-423). Bombay Natural History Society. Bombay and Oxford University Press, New Delhi, India.

Sparks, D. R., & Malechek, J. C. (1968). Estimating percentage dry weight in diets using a microscopic technique. *Rangeland Ecology and Management/Journal of Range Management Archives*, *21* (4), 264-265.

Spencer, E. E., Crowther, M. S., & Dickman, C. R. (2014). Diet and prey selectivity of three species of sympatric mammalian predators in central Australia. *Journal of Mammalogy, 95*(6), 1278-1288.

Spillett, J. J. (1966). A report on wild life surveys in North India and Southern Nepal: The Kaziranga Wild Life Sanctuary, Assam. *Journal of the Bombay Natural History Society*, *63*, 494-533.

Steinheim, G., Wegge, P., Fjellstad, J. I., Jnawali, S. R. & Weladji, R. B. (2005). Dry season diets and habitat use of sympatric Asian elephants (*Elephas maximus*) and greater one-horned rhinoceros (*Rhinocerus unicornis*) in Nepal. *Journal of Zoology, 265*(4), 377–385.

Stewart, D. R. M. (1967). Analysis of Plant Epidermis in Faeces: A Technique for Studying the Food Preferences of Grazing Herbivores. *Journal of Applied Ecology, 4*(1), 83-111.

Styles, C. V., & Skinner, J. D. (1997). Seasonal variations in the quality of mopane leaves as a source of browse for mammalian herbivores. *African Journal of Ecology*, *35*(3), 254-265.

Sukumar, R. (1989). Ecology of the Asian elephant in Southern India. I. Movement and habitat utilization patterns. *Journal of Tropical Ecology*, *5*(1), 1-18.

Sukumar, R. (1990). Ecology of the Asian elephant in Southern India. II. Feeding habits and crop raiding patterns. *Journal of Tropical Ecology*, *6*(1), 33-53.

Sukumar, R. (2003). *The living elephants: Evolutionary ecology, behavior, and conservation.* Oxford University Press, New York. 478pp.

Sukumar, R., & Santiapillai, C. (2006). Planning for Asian elephant conservation. *Gajah*, *25*, 9-20.

Talukdar, B. K. (1999). Status of *Rhinoceros unicornis* in Pabitora Wildlife Sanctuary, Assam. *Tiger Paper, 1*(1), 8-10.

Tandon, V. (1989). Conservation status of hog deer *Cervus porcinus* in India and adjacent areas. *IUCN/SSC Deer Specialist Group Newsletter, 7*.

Terborgh, J. (1983). *Five New World Primates: A Study in Comparative Ecology*. Princeton University Press, New Jersey. 276pp.

Tewari, R., & Rawat, G. S. (2013). Studies on the Food and Feeding Habits of Swamp Deer (*Rucervus duvaucelii duvaucelii*) in Jhilmil Jheel Conservation Reserve, Haridwar, Uttarakhand, India. *International Scholarly Research Notices Zoology, 2013,* 1-6.

Thapa, S. K., de Jong, J. F., Subedi, N., Hof, A. R., Corradini, G., Basnet, S., & Prins, H. H. T. (2021). Forage quality in grazing lawns and tall grasslands in the subtropical region of Nepal and implications for wild herbivores. *Global Ecology and Conservation*, *30*, e01747.

Tiwari, R. (2009). *A study on the habitat use and food habits of swamp deer (Cervus duvauceli duvauceli) in Jhilmil Jheel Conversation Reserve, Haridwar Forest Division, Uttarakhand.* Doctoral Thesis, Saurashtra University.

Tiwari, S. K. (2000). *A study of the Ecology and behavior of Asian Elephants (Elephas maximus) in Chandaka Wildlife Sanctuary, Orissa.* Doctoral Thesis, Burdwan University, West Bengal.

Todd, J. W., & Hansen, R. M. (1973). Plant Fragments in the Feces of Bighorns as Indicators of Food Habits. *The Journal of Wildlife Management, 37*(3), 363-366.

Tuboi, C., & Hussain, S. A. (2016). Factors affecting forage selection by the endangered Eld's deer and hog deer in the floating meadows of Barak-Chindwin Basin of North-east India. *Mammalian Biology-Zeitschrift für Säugetierkunde*, *81* (1), 53-60.

Ullah, M. I., & Aslam, D. M. (2018). *Mctest: Multicollinearity Diagnostic Measures.* R package version, *1*(1).

Uniyal, S. K., Awasthi, A., & Rawat, G. S. (2005). Biomass availability and forage quality of *Eurotia ceratoides* Mey in the rangelands of Changthang, eastern Ladakh. *Current Science*, *89*(1), 201-205.

van Langevelde, F., Drescher, M., Heitkönig, I. M. A., & Prins, H. H. T. (2008). Instantaneous intake rate of herbivores as function of forage quality and mass: Effects on facilitative and competitive interactions. *Ecological Modelling*, *213*(3-4), 273-284.

Van Soest, P. J. (1967). Development of a comprehensive system of feed analyses and its application to forages. *Journal of Animal Science*, *26*(1), 119-128.

Van Soest, P. J. (1982). *Nutritional Ecology of the Ruminant* (1st ed.). Corvallis, Oregon: O & B Books. 374pp.

Van Soest, P. J. (1996). Allometry and ecology of feeding behavior and digestive capacity in herbivores: A review. *Zoo Biology*, *15*(5), 455-479.

Vancuylenberg, B. W. B. (1977). Feeding behaviour of the Asiatic elephant in South-East Sri Lanka in relation to conservation. *Biological Conservation*, *12*(1), 33-54.

Varman, K, & Sukumar, K. (1993). Ecology of sambar in Mudumalai Sanctuary, Southern India. In Menzel, K., Ohtaishi, N., & Sheng, H. (Eds.). *Deer of China: Biology and Management,* (pp. 273-284). Elsevier Science Publishers.

Vasu, N. K., & Singh, G. (2015). Grasslands of Kaziranga National Park: Problems and approaches for management. In G. S. Rawat & B. S. Adhikari (Eds.). *Ecology and Management of Grassland Habitats in India, ENVIS Bulletin: Wildlife & protected areas* (pp. 104–113). Dehradun, India: Wildlife Institute of India.

Veldhuis, M. P., Fakkert, H. F., Berg, M. P., & Olff, H. (2016). Grassland structural heterogeneity in a savanna is driven more by productivity differences than by consumption differences between lawn and bunch grasses. *Oecologia*, *182*(3), 841-853.

Vesey-FitzGerald, D. F. (1960). Grazing succession among East African game animals. *Journal of Mammalogy, 41*(2), 161-172.

Vila, A. R., Galende, G. I., & Pastore, H. (2009). Feeding ecology of the endangered huemul (*Hippocamelus bisulcus*) in Los Alerces National Park, Argentina. *Mastozoología Neotropical*, *16*(2), 423-431.

Wardle, D. (2010). Trophic cascades, aboveground and belowground linkages, and ecosystem functioning. In Terborgh, J. & Estes, J. A. (Eds.). *Trophic Cascades: Predators, Prey, and the Changing Dynamics of Nature* (pp. 203-17). Island Press, Washington, DC.

Wegge, P., Shrestha, A. K., & Moe, S. R. (2006). Dry season diets of sympatric ungulates in lowland Nepal: Competition and facilitation in alluvial tall grasslands. *Ecological Research*, *21*(5), 698-706.

Wei, T., Simko, V., Levy, M., Xie, Y., Jin, Y., & Zemla, J. (2017). Visualization of a correlation matrix. *Statistician*, *56*, 316-324.

Westoby, M. (1978). What are the biological basis of varied diets? *The American Naturalist*, *112*(985), 627-631.

Wilby, A., Shachak, M., & Boeken, B. (2001). Integration of ecosystem engineering and trophic effects of herbivores. *Oikos*, *92*(3), 436-444.

Wilson, D. E., & Mittermeier, R. A. (2011). *Handbook of the Mammals of the World, Volume 2: Hoofed Mammals*. Lynx Edicions. 885pp.

Wilson, D. E., & Reeder, D. M. (Eds.). (2005). *Mammal Species of the World: A Taxonomic and Geographic Reference* (1st Volume). Johns Hopkins University Press, Baltimore, Maryland.

Yadava, M. K. (2014). Detailed report on issues and possible solutions for long term protection of the greater one horned rhinoceros in Kaziranga National Park. *Government of Assam, Kaziranga National Park*.

Zhang, J. (2013). *Spaa: Species Association Analysis.* R package version 0. 2. 1.

APPENDICES

Appendix 1. Faunal diversity documented from Kaziranga Tiger Reserve, Assam (No. of species [literature])*

Classes	No. of species documented from literature													Present Study
Mammalia	2[1]	1[2]	1[3]	23[4]	6[5]	1[6]	3[7]	31[8]	22[9]	1[10]	44[11]	54[12]	2[13]	66
Aves	223[14]	481[15]	1[16]	215[17]	1[18]	1[19]	1[20]	514[11]						559
Reptilia	1[14]	10[21]	5[22]	74[23]	4[17]	23[24]	16[25]							75
Actinopterygii	40[14]	1[26]	5[27]	42[8]	30[28]	1[29]								80
Amphibia	7[30]	24[23]												24
Insecta	36[31]	96[32]	137[33]	116[34]	82[35]									467
Total Documented taxa														**1271**

* [1] Spillett (1967), [2] Gee (1967), [3] Choudhary (1999), [4] Banerjee (2001), [5] Choudhury (2001), [6] Molur (2005), [7] Choudhury (2011), [8] Vasu (2003), [9] Menon (2014), [10] Qureshi et al., (2015), [11] Rahmani et al. (2016), [12] Sharma (2018), [13] Boro et al., (2018), [14] Pathak (1978), [15] Barua & Sharma (1999), [16] Barman (2005), [17] Baruah (2007), [18] Borthakur & Das (2010), [19] Saikia & Saikia (2015), [20] Choudhary (2014), [21]Bhupathy et al. (1992), [22] Choudhury (2004), [23] Ahmed et al. (2005), [24] Das et al. (2007), [25] Basumatary & Sharma (2013), [26] Tilak & Sati (1984), [27] Menon (1999), [28] Laskar et al., (2018), [29] Kullender et al. (2018), [30] Chanda (1994), 31 Senthilkumar (2010), [32] Singh & Varatharajan (2013), [33] Gogoi (2013), [34] Gogoi (2015), [35] Boruah et al., (2016) and P- Recorded from Present study.

Appendix 2. Mammalia diversity in Kaziranga Tiger Reserve, Assam

S.No.	Order	Family	Scientific name (IUCN)	Literature
1	Carnivora	Canidae	*Canis aureus* (Linnaeus, 1758)	8, 9, 11, 12
2	Carnivora	Canidae	*Cuon alpinus* (Pallas, 1811)	1
3	Carnivora	Canidae	*Vulpes bengalensis* (Shaw, 1800)	8, 12
4	Carnivora	Felidae	*Felis chaus* (Schreber, 1777)	P, 4, 8, 9, 11, 12
5	Carnivora	Felidae	*Panthera pardus* (Linnaeus, 1758)	P, 4, 8, 11, 12
6	Carnivora	Felidae	*Panthera tigris* (Linnaeus, 1758)	P, 4, 8, 11, 12
7	Carnivora	Felidae	*Prionailurus bengalensis* (Kerr, 1792)	11, 12
8	Carnivora	Felidae	*Prionailurus viverrinus* (Bennett, 1833)	P, 8, 11, 12
9	Carnivora	Herpestidae	*Herpestes edwardsii* (É. Geoffroy Saint-Hilaire, 1818)	4, 8, 11, 12
10	Carnivora	Herpestidae	*Herpestes javanicus* (É. Geoffroy Saint-Hilaire, 1818)	8, 11, 12
11	Carnivora	Herpestidae	*Herpestes urva* (Hodgson, 1836)	12
12	Carnivora	Hyaenidae	*Hyaena hyaena* (Linnaeus, 1758)	12
13	Carnivora	Mustelidae	*Aonyx cinereus* (Illiger, 1815)	4, 9
14	Carnivora	Mustelidae	*Arctonyx collaris* (F.G. Cuvier, 1825)	8, 9, 11, 12
15	Carnivora	Mustelidae	*Lutra lutra* (Linnaeus, 1758)	P, 1, 4, 8, 11, 12
16	Carnivora	Mustelidae	*Lutrogale perspicillata* (I. Geoffroy Saint-Hilaire, 1826)	4, 11, 12
17	Carnivora	Mustelidae	*Martes flavigula* (Boddaert, 1785)	12
18	Carnivora	Mustelidae	*Mellivora capensis* (Schreber, 1776)	3
19	Carnivora	Mustelidae	*Melogale moschata* (Gray, 1831)	8, 12
20	Carnivora	Prionodontidae	*Prionodon pardicolor* (Hodgson, 1841)	11
21	Carnivora	Ursidae	*Helarctos malayanus* (Raffles, 1821)	2, 7, 10
22	Carnivora	Ursidae	*Melursus ursinus* (Shaw, 1791)	4, 7, 8, 11, 12
23	Carnivora	Ursidae	*Ursus thibetanus* (G. [Baron] Cuvier, 1823)	7, 11, 1214
24	Carnivora	Viverridae	*Paradoxurus hermaphroditus* (Pallas, 1777)	9, 11, 12
25	Carnivora	Viverridae	*Viverra zibetha* (Linnaeus, 1758)	P, 8, 11, 12
26	Carnivora	Viverridae	*Viverricula indica* (É. Geoffroy Saint-Hilaire, 1803)	8, 11, 12
27	Cetartiodactyla	Bovidae	*Bos gaurus* (C.H. Smith, 1827)	4, 8, 11, 12
28	Cetartiodactyla	Bovidae	*Bubalus arnee* (Kerr, 1792)	P, 4, 8, 9, 11, 12
29	Cetartiodactyla	Cervidae	*Axis porcinus* (Zimmermann, 1780)	P, 4, 8, 9, 11, 12
30	Cetartiodactyla	Cervidae	*Muntiacus muntjak* (Zimmermann, 1780)	P, 4, 8, 9, 11,12
31	Cetartiodactyla	Cervidae	*Rucervus duvaucelii* (G. Cuvier, 1823)	P, 4, 8, 9, 11, 12
32	Cetartiodactyla	Cervidae	*Rusa unicolor* (Kerr, 1792)	P, 4, 8, 11, 12
33	Cetartiodactyla	Platanistidae	*Platanista gangetica* (Roxburgh, 1801)	4, 8, 9, 12
34	Cetartiodactyla	Suidae	*Sus scrofa* (Linnaeus, 1758)	P, 4, 8, 11, 12
35	Chiroptera	Pteropodidae	*Pteropus giganteus* (Brünnich, 1782)	12
36	Chiroptera	Pteropodidae	*Rousettus leschenaultii* (Desmarest, 1820)	13
37	Chiroptera	Vespertilionidae	*Kerivoula picta* (Pallas, 1767)	13
38	Eulipotyphla	Soricidae	*Crocidura attenuata* (Milne-Edwards, 1872)	11, 12
39	Eulipotyphla	Soricidae	*Suncus murinus* (Linnaeus, 1766)	11, 12
40	Eulipotyphla	Talpidae	*Euroscaptor micrura* (Hodgson, 1841)	6, 11
41	Logomorpha	Leporidae	*Caprolagus hispidus* (Pearson, 1839)	12

S.No.	Order	Family	Scientific name (IUCN)	Literature
42	Logomorpha	Leporidae	*Lepus nigricollis* (F. Cuvier, 1823)	4, 9, 11, 12
43	Perissodactyla	Rhinocerotidae	*Rhinoceros unicornis* (Linnaeus, 1758)	P, 4, 8, 9, 11, 12
44	Pholidota	Manidae	*Manis crassicaudata* (É. Geoffroy, 1803)	8, 12
45	Pholidota	Manidae	*Manis pentadactyla* (Linnaeus, 1758)	11, 12
46	Primates	Cercopithecidae	*Macaca assamensis* (M'Clelland, 1840)	5, 8, 9, 11, 12
47	Primates	Cercopithecidae	*Macaca mulatta* (Zimmermann, 1780)	P, 4, 5, 8, 9, 11, 12
48	Primates	Cercopithecidae	*Trachypithecus geei* (Khajuria, 1956)	5
49	Primates	Cercopithecidae	*Trachypithecus phayrei* (Blyth, 1847)	5, 12
50	Primates	Cercopithecidae	*Trachypithecus pileatus* (Blyth, 1843)	P, 4, 5, 8, 9, 11, 12
51	Primates	Hylobatidae	*Hoolock hoolock* (Harlan, 1834)	P, 4, 8, 9, 11, 12
52	Primates	Lorisidae	*Nycticebus bengalensis* (Lacépède, 1800)	5, 9, 11, 12
53	Proboscidea	Elephantidae	*Elephas maximus* (Linnaeus, 1758)	P, 4, 8, 9, 11, 12
54	Rodentia	Hystricidae	*Atherurus macrourus* (Linnaeus, 1758)	11
55	Rodentia	Hystricidae	*Hystrix brachyura* (Linnaeus, 1758)	11, 12
56	Rodentia	Hystricidae	*Hystrix indica* (Kerr, 1792)	P, 4, 8, 12
57	Rodentia	Muridae	*Bandicota indica* (Bechstein, 1800)	12
58	Rodentia	Muridae	*Micromys minutus* (Pallas, 1771)	12
59	Rodentia	Muridae	*Mus musculus* (Linnaeus, 1758)	12
60	Rodentia	Sciuridae	*Callosciurus erythraeus* (Pallas, 1779)	12
61	Rodentia	Sciuridae	*Callosciurus pygerythrus* (I. Geoffroy Saint Hilaire, 1832)	P, 9, 11
62	Rodentia	Sciuridae	*Dremomys lokriah* (Hodgson, 1836)	8, 11, 12
63	Rodentia	Sciuridae	*Hylopetes alboniger* (Hodgson, 1836)	9, 11, 12
64	Rodentia	Sciuridae	*Ratufa bicolor* (Sparrman, 1778)	9, 11, 12
65	Rodentia	Sciuridae	*Tamiops mcclellandii* (Horsfield, 1840)	P, 9, 11, 12
66	Scandentia	Tupaiidae	*Tupaia belangeri* (Wagner, 1841)	11

Population- Population trend from IUCN (2022), IUCN status- International Union for Conservation of Nature, LC- Least Concern, NT- Near Threatened, VU- Vulnerable, EN- Endangered, CR- Critically Endangered, IWPA- Wild Life (Protection) Act, 1972, CITES- Convention on International Trade in Endangered Species of Wild Fauna and Flora, P- recorded during present study, 1- Spillett (1967), 2- Gee (1967), 3- Choudhary (1999), 4- Banerjee (2001), 5- Choudhury (2001), 6- Molur (2005), 7- Choudhury (2011), 8- Vasu (2003), 9- Menon (2014), 10- Qureshi et al., (2015), 11- Rahmani et al. (2016), 12- Sharma (2018), 13- Boro et al., (2018), 14- Borah et al., 2022

Appendix 3. Aves diversity in Kaziranga Tiger Reserve, Assam

S.No.	Order	Family	Scientific name (IUCN)	Literature
1	Accipitriformes	Accipitridae	*Accipiter badius* (Gmelin, 1788)	1, 2, 4, 8
2	Accipitriformes	Accipitridae	*Accipiter gentilis* (Linnaeus, 1758)	2
3	Accipitriformes	Accipitridae	*Accipiter gularis* (Temminck & Schlegel, 1844)	2, 8
4	Accipitriformes	Accipitridae	*Accipiter nisus* (Linnaeus, 1758)	2, 4, 8
5	Accipitriformes	Accipitridae	*Accipiter trivirgatus* (Temminck, 1824)	2, 8
6	Accipitriformes	Accipitridae	*Accipiter virgatus* (Temminck, 1822)	8
7	Accipitriformes	Accipitridae	*Aegypius monachus* (Linnaeus, 1766)	1, 2, 8
8	Accipitriformes	Accipitridae	*Aquila fasciata* (Vieillot, 1822)	1, 2, 8
9	Accipitriformes	Accipitridae	*Aquila heliaca* (Savigny, 1809)	2, 4, 8
10	Accipitriformes	Accipitridae	*Aquila nipalensis* (Hodgson, 1833)	P, 2, 4, 8
11	Accipitriformes	Accipitridae	*Aviceda jerdoni* (Blyth, 1842)	2, 8
12	Accipitriformes	Accipitridae	*Aviceda leuphotes* (Dumont, 1820)	1, 2, 8
13	Accipitriformes	Accipitridae	*Butastur teesa* (Franklin, 1831)	2, 8
14	Accipitriformes	Accipitridae	*Buteo buteo* (Linnaeus, 1758)	2, 8
15	Accipitriformes	Accipitridae	*Buteo rufinus* (Cretzschmar, 1827)	2, 8
16	Accipitriformes	Accipitridae	*Circaetus gallicus* (Gmelin, 1788)	1, 2, 8
17	Accipitriformes	Accipitridae	*Circus aeruginosus* (Linnaeus, 1758)	1, 2, 4, 8
18	Accipitriformes	Accipitridae	*Circus cyaneus* (Linnaeus, 1766)	2, 8
19	Accipitriformes	Accipitridae	*Circus macrourus* (S. G. Gmelin, 1770)	1, 8
20	Accipitriformes	Accipitridae	*Circus melanoleucos* (Pennant, 1769)	1, 2, 4, 8
21	Accipitriformes	Accipitridae	*Circus pygargus* (Linnaeus, 1758)	2, 8
22	Accipitriformes	Accipitridae	*Clanga clanga* (Pallas, 1811)	2, 4, 8
23	Accipitriformes	Accipitridae	*Clanga hastata* (Lesson, 1831)	4, 8
24	Accipitriformes	Accipitridae	*Clanga pomarina* (Brehm, 1831)	2
25	Accipitriformes	Accipitridae	*Elanus caeruleus* (Desfontaines, 1789)	1, 2, 4, 8
26	Accipitriformes	Accipitridae	*Gyps bengalensis* (Gmelin, 1788)	1, 2, 4, 8
27	Accipitriformes	Accipitridae	*Gyps fulvus* (Hablizl, 1783)	1, 2, 4, 8
28	Accipitriformes	Accipitridae	*Gyps himalayensis* (Hume, 1869)	2, 8
29	Accipitriformes	Accipitridae	*Gyps indicus* (Scopoli, 1786)	P, 1, 2, 8
30	Accipitriformes	Accipitridae	*Gyps tenuirostris* (Gray, 1844)	P, 4, 8
31	Accipitriformes	Accipitridae	*Haliaeetus albicilla* (Linnaeus, 1758)	2, 8

S.No.	Order	Family	Scientific name (IUCN)	Literature
32	Accipitriformes	Accipitridae	*Haliaeetus leucoryphus* (Pallas, 1771)	P, 1, 2, 4, 8
33	Accipitriformes	Accipitridae	*Haliastur indus* (Boddaert, 1783)	P, 1, 2, 8
34	Accipitriformes	Accipitridae	*Hieraaetus pennatus* (Gmelin, 1788)	2, 8
35	Accipitriformes	Accipitridae	*Icthyophaga humilis* (Müller & Schlegel, 1841)	8
36	Accipitriformes	Accipitridae	*Icthyophaga ichthyaetus* (Horsfield, 1821)	P, 1, 2, 4, 8
37	Accipitriformes	Accipitridae	*Ictinaetus malaiensis* (Temminck, 1822)	2, 8
38	Accipitriformes	Accipitridae	*Lophotriorchis kienerii* (Geoffroy Saint-Hilaire, 1835)	2, 8
39	Accipitriformes	Accipitridae	*Milvus migrans govinda* (Sykes, 1832)	1, 4, 8
40	Accipitriformes	Accipitridae	*Milvus migrans* (Boddaert, 1783)	P, 2, 8
41	Accipitriformes	Accipitridae	*Nisaetus cirrhatus* (Gmelin, 1788)	P, 2, 4, 8
42	Accipitriformes	Accipitridae	*Nisaetus nipalensis* (Hodgson, 1836)	2, 4, 8
43	Accipitriformes	Accipitridae	*Pernis ptilorhynchus* (Temminck, 1821)	2, 4, 8
44	Accipitriformes	Accipitridae	*Sarcogyps calvus* (Scopoli, 1786)	1, 2, 8
45	Accipitriformes	Accipitridae	*Spilornis cheela* (Latham, 1790)	P, 1, 2, 4, 8
46	Accipitriformes	Pandionidae	*Pandion haliaetus* (Linnaeus, 1758)	1, 2, 4, 8
47	Anseriformes	Anatidae	*Anas acuta* (Linnaeus, 1758)	P, 1, 2, 4, 8
48	Anseriformes	Anatidae	*Anas crecca* (Linnaeus, 1758)	P, 1, 2, 4, 8
49	Anseriformes	Anatidae	*Anas platyrhynchos* (Linnaeus, 1758)	P, 1, 2, 4, 8
50	Anseriformes	Anatidae	*Anas poecilorhynch*	P, 1, 2, 4, 8
51	Anseriformes	Anatidae	*Anser albifrons* (Scopoli, 1769)	8
52	Anseriformes	Anatidae	*Anser anser* (Linnaeus, 1758)	P, 1, 2, 4, 8
53	Anseriformes	Anatidae	*Anser erythropus*	P, 2, 8
54	Anseriformes	Anatidae	*Anser indicus* (Latham, 1790)	P, 1, 2, 4, 8
55	Anseriformes	Anatidae	*Aythya baeri* (Radde, 1863)	2, 8
56	Anseriformes	Anatidae	*Aythya ferina* (Linnaeus, 1758)	1, 2, 8
57	Anseriformes	Anatidae	*Aythya fuligula* (Linnaeus, 1758)	1, 2, 4, 8
58	Anseriformes	Anatidae	*Aythya nyroca* (Güldenstädt, 1770)	P, 1, 2, 8
59	Anseriformes	Anatidae	*Dendrocygna bicolor* (Vieillot, 1816)	2, 8
60	Anseriformes	Anatidae	*Dendrocygna javanica* (Horsfield, 1821)	P, 1, 2, 8
61	Anseriformes	Anatidae	*Mareca falcata* (Georgi, 1775)	2, 8
62	Anseriformes	Anatidae	*Mareca penelope* (Linnaeus, 1758)	P, 1, 2, 4, 8
63	Anseriformes	Anatidae	*Mareca strepera* (Linnaeus, 1758)	1, 2, 4, 8
64	Anseriformes	Anatidae	*Mergellus albellus* (Linnaeus, 1758)	2, 8
65	Anseriformes	Anatidae	*Netta rufina* (Pallas, 1773)	2, 8
66	Anseriformes	Anatidae	*Nettapus coromandelianus* (Gmelin, 1789)	1, 2, 8
67	Anseriformes	Anatidae	*Spatula clypeata* (Linnaeus, 1758)	P, 1, 2, 4, 8
68	Anseriformes	Anatidae	*Spatula querquedula* (Linnaeus, 1758)	1, 2, 4, 8
69	Anseriformes	Anatidae	*Tadorna ferruginea* (Pallas, 1764)	P, 1, 2, 8
70	Anseriformes	Anatidae	*Tadorna tadorna* (Linnaeus, 1758)	2, 8
71	Bucerotiformes	Bucerotidae	*Anthracoceros albirostris* (Shaw & Nodder, 1807)	1, 2, 4, 8
72	Bucerotiformes	Bucerotidae	*Anthracoceros coronatus* (Boddaert, 1783)	1
73	Bucerotiformes	Bucerotidae	*Buceros bicornis* (Linnaeus, 1758)	P, 1, 2, 4, 8
74	Bucerotiformes	Bucerotidae	*Rhyticeros undulatus* (Shaw, 1811)	P, 2, 8
75	Bucerotiformes	Upupidae	*Upupa epops* (Linnaeus, 1758)	P, 1, 2, 4, 8
76	Caprimulgiformes	Apodidae	*Aerodramus brevirostris* (Horsfield, 1840)	2, 8
77	Caprimulgiformes	Apodidae	*Aerodramus fuciphagus* (Thunberg, 1812)	1
78	Caprimulgiformes	Apodidae	*Apus affinis* (Gray, 1830)	P, 1, 2, 4, 8
79	Caprimulgiformes	Apodidae	*Apus pacificus leuconyx* (Blyth, 1845)	8
80	Caprimulgiformes	Apodidae	*Cypsiurus balasiensis* (Gray, 1829)	2, 4, 8
81	Caprimulgiformes	Apodidae	*Hirundapus caudacutus* (Latham, 1802)	8
82	Caprimulgiformes	Apodidae	*Hirundapus cochinchinensis* (Oustalet, 1878)	2, 8
83	Caprimulgiformes	Apodidae	*Hirundapus giganteus* (Temminck, 1825)	2, 8
84	Caprimulgiformes	Apodidae	*Zoonavena sylvatica* (Tickell, 1846)	8
85	Caprimulgiformes	Caprimulgidae	*Caprimulgus affinis* (Horsfield, 1821)	P, 2, 8
86	Caprimulgiformes	Caprimulgidae	*Caprimulgus asiaticus* (Latham, 1790)	1
87	Caprimulgiformes	Caprimulgidae	*Caprimulgus indicus* (Latham, 1790)	2
88	Caprimulgiformes	Caprimulgidae	*Caprimulgus jotaka* Temminck & Schlegel, 1847	8
89	Caprimulgiformes	Caprimulgidae	*Caprimulgus macrurus* (Horsfield, 1821)	1, 2, 8
90	Charadriiformes	Burhinidae	*Burhinus indicus* (Salvadori, 1865)	8
91	Charadriiformes	Burhinidae	*Esacus recurvirostris* (Cuvier, 1829)	P, 2, 8
92	Charadriiformes	Charadriidae	*Charadrius alexandrinus* (Linnaeus, 1758)	2, 8
93	Charadriiformes	Charadriidae	*Charadrius dubius* (Scopoli, 1786)	P, 1, 2, 4, 8
94	Charadriiformes	Charadriidae	*Charadrius mongolus* (Pallas, 1776)	2, 8
95	Charadriiformes	Charadriidae	*Charadrius placidus* (Gray & Gray, 1863)	4, 8
96	Charadriiformes	Charadriidae	*Pluvialis fulva* (Gmelin, 1789)	2, 8
97	Charadriiformes	Charadriidae	*Vanellus cinereus* (Blyth, 1842)	P, 1, 2, 4, 8
98	Charadriiformes	Charadriidae	*Vanellus duvaucelii* (Lesson, 1826)	P, 2, 8

S.No.	Order	Family	Scientific name (IUCN)	Literature
99	Charadriiformes	Charadriidae	*Vanellus gregarius* (Pallas, 1771)	1
100	Charadriiformes	Charadriidae	*Vanellus indicus* (Boddaert, 1783)	P, 1, 2, 4, 8
101	Charadriiformes	Charadriidae	*Vanellus spinosus* (Linnaeus, 1758)	1
102	Charadriiformes	Charadriidae	*Vanellus vanellus* (Linnaeus, 1758)	P, 1, 2, 4, 8
103	Charadriiformes	Glareolidae	*Glareola lactea* (Temminck, 1820)	2, 8
104	Charadriiformes	Glareolidae	*Glareola maldivarum* (Forster, 1795)	8
105	Charadriiformes	Jacanidae	*Hydrophasianus chirurgus* (Scopoli, 1786)	P, 1, 2, 8
106	Charadriiformes	Jacanidae	*Metopidius indicus* (Latham, 1790)	P, 1, 2, 4, 8
107	Charadriiformes	Laridae	*Chlidonias hybrida* (Pallas, 1811)	P, 1, 2, 8
108	Charadriiformes	Laridae	*Chlidonias leucopterus* (Temminck, 1815)	2, 8
109	Charadriiformes	Laridae	*Gelochelidon nilotica* (Gmelin, 1789)	2, 8
110	Charadriiformes	Laridae	*Hydrocoloeus minutus* (Pallas, 1776)	2, 8
111	Charadriiformes	Laridae	*Larus brunnicephalus* (Jerdon, 1840)	1, 2, 8
112	Charadriiformes	Laridae	*Larus ridibundus* (Linnaeus, 1766)	2, 8
113	Charadriiformes	Laridae	*Rynchops albicollis* (Swainson, 1838)	7
114	Charadriiformes	Laridae	*Sterna acuticauda* (Gray, 1832)	1, 2, 8
115	Charadriiformes	Laridae	*Sterna aurantia* (Gray, 1831)	1, 2, 4, 8
116	Charadriiformes	Laridae	*Sterna hirundo* (Linnaeus, 1758)	2, 8
117	Charadriiformes	Laridae	*Sternula albifrons* (Pallas, 1764)	2, 8
118	Charadriiformes	Recurvirostridae	*Himantopus himantopus* (Linnaeus, 1758)	2, 8
119	Charadriiformes	Recurvirostridae	*Recurvirostra avosetta* (Linnaeus, 1758)	2, 8
120	Charadriiformes	Rostratulidae	*Rostratula benghalensis* (Linnaeus, 1758)	2, 8
121	Charadriiformes	Scolopacidae	*Actitis hypoleucos* (Linnaeus, 1758)	P, 1, 2, 4, 8
122	Charadriiformes	Scolopacidae	*Calidris minuta* (Leisler, 1812)	2, 4, 8
123	Charadriiformes	Scolopacidae	*Calidris pugnax* (Linnaeus, 1758)	2, 8
124	Charadriiformes	Scolopacidae	*Calidris temminckii* (Leisler, 1812)	1, 2, 4, 8
125	Charadriiformes	Scolopacidae	*Calidris tenuirostris* (Horsfield, 1821)	2, 8
126	Charadriiformes	Scolopacidae	*Gallinago gallinago* (Linnaeus, 1758)	P, 1, 2, 4, 8
127	Charadriiformes	Scolopacidae	*Gallinago megala* (Swinhoe, 1861)	2, 8
128	Charadriiformes	Scolopacidae	*Gallinago stenura* (Bonaparte, 1830)	2, 4, 8
129	Charadriiformes	Scolopacidae	*Limosa limosa* (Linnaeus, 1758)	2, 8
130	Charadriiformes	Scolopacidae	*Lymnocryptes minimus* (Brünnich, 1764)	2, 4, 8
131	Charadriiformes	Scolopacidae	*Numenius arquata* (Linnaeus, 1758)	2, 8
132	Charadriiformes	Scolopacidae	*Phalaropus lobatus* (Linnaeus, 1758)	2, 8
133	Charadriiformes	Scolopacidae	*Tringa erythropus* (Pallas, 1764)	1, 2, 4, 8
134	Charadriiformes	Scolopacidae	*Tringa glareola* (Linnaeus, 1758)	P, 2, 8
135	Charadriiformes	Scolopacidae	*Tringa guttifer* (Nordmann, 1835)	2, 8
136	Charadriiformes	Scolopacidae	*Tringa nebularia* (Gunnerus, 1767)	1, 2, 4, 8
137	Charadriiformes	Scolopacidae	*Tringa ochropus* (Linnaeus, 1758)	1, 2, 4, 8
138	Charadriiformes	Scolopacidae	*Tringa stagnatilis* (Bechstein, 1803)	1, 2, 4, 8
139	Charadriiformes	Scolopacidae	*Tringa totanus* (Linnaeus, 1758)	2, 4, 8
140	Charadriiformes	Scolopacidae	*Xenus cinereus* (Güldenstädt, 1775)	2, 8
141	Charadriiformes	Turnicidae	*Turnix suscitator* (Gmelin, 1789)	2, 8
142	Charadriiformes	Turnicidae	*Turnix tanki* (Blyth, 1843)	2, 8
143	Ciconiiformes	Ciconiidae	*Anastomus oscitans* (Boddaert, 1783)	P, 1, 2, 4, 8
144	Ciconiiformes	Ciconiidae	*Ciconia ciconia* (Linnaeus, 1758)	P, 2, 8
145	Ciconiiformes	Ciconiidae	*Ciconia episcopus* (Boddaert, 1783)	P, 1, 2, 4, 8
146	Ciconiiformes	Ciconiidae	*Ciconia nigra* (Linnaeus, 1758)	P, 1, 2, 8
147	Ciconiiformes	Ciconiidae	*Ephippiorhynchus asiaticus* (Latham, 1790)	P, 1, 2, 4, 8
148	Ciconiiformes	Ciconiidae	*Leptoptilos dubius* (Gmelin, 1789)	P, 1, 2, 4, 8
149	Ciconiiformes	Ciconiidae	*Leptoptilos javanicus* (Horsfield, 1821)	P, 1, 2, 4, 8
150	Columbiformes	Columbidae	*Chalcophaps indica* (Linnaeus, 1758)	P, 1, 2, 4, 8
151	Columbiformes	Columbidae	*Columba livia* (Gmelin, 1789)	P, 2, 4, 8
152	Columbiformes	Columbidae	*Columba punicea* (Blyth, 1842)	2, 8
153	Columbiformes	Columbidae	*Ducula aenea* (Linnaeus, 1766)	P, 1, 2, 4, 8
154	Columbiformes	Columbidae	*Ducula badia* (Raffles, 1822)	2, 8
155	Columbiformes	Columbidae	*Macropygia unchall* (Wagler, 1827)	8
156	Columbiformes	Columbidae	*Spilopelia chinensis* (Scopoli, 1786)	P, 1, 2, 4, 8
157	Columbiformes	Columbidae	*Streptopelia decaocto* (Frivaldszky, 1838)	1, 2, 8
158	Columbiformes	Columbidae	*Streptopelia orientalis* (Latham, 1790)	P, 1, 2, 4, 8
159	Columbiformes	Columbidae	*Streptopelia tranquebarica* (Hermann, 1804)	P, 1, 2, 4, 8
160	Columbiformes	Columbidae	*Treron apicauda* (Blyth, 1846)	8
161	Columbiformes	Columbidae	*Treron bicinctus* (Jerdon, 1840)	1, 2, 8
162	Columbiformes	Columbidae	*Treron curvirostra* (Gmelin, 1789)	2, 8
163	Columbiformes	Columbidae	*Treron phayrei* (Blyth, 1862)	8
164	Columbiformes	Columbidae	*Treron phoenicopterus* (Latham, 1790)	P, 1, 2, 4, 8
165	Columbiformes	Columbidae	*Treron pompadora* (Gmelin, 1789)	2

S.No.	Order	Family	Scientific name (IUCN)	Literature
166	Columbiformes	Columbidae	*Treron sphenurus* (Vigors, 1832)	2, 8
167	Coraciiformes	Alcedinidae	*Alcedo atthis* (Linnaeus, 1758)	P, 1, 2, 4, 8
168	Coraciiformes	Alcedinidae	*Alcedo hercules* (Laubmann, 1917)	P, 2, 8
169	Coraciiformes	Alcedinidae	*Alcedo meninting* (Horsfield, 1821)	1, 2, 8
170	Coraciiformes	Alcedinidae	*Ceryle rudis* (Linnaeus, 1758)	P, 1, 2, 4, 8
171	Coraciiformes	Alcedinidae	*Halcyon coromanda* (Latham, 1790)	P, 2, 8
172	Coraciiformes	Alcedinidae	*Halcyon pileata* (Boddaert, 1783)	2, 8
173	Coraciiformes	Alcedinidae	*Halcyon smyrnensis* (Linnaeus, 1758)	P, 1, 2, 4, 8
174	Coraciiformes	Alcedinidae	*Pelargopsis capensis* (Linnaeus, 1766)	P, 1, 2, 4, 8
175	Coraciiformes	Coraciidae	*Coracias benghalensis* (Linnaeus, 1758)	P, 1, 2, 4, 8
176	Coraciiformes	Coraciidae	*Eurystomus glaucurus* (Müller, 1776)	1
177	Coraciiformes	Coraciidae	*Eurystomus orientalis* (Linnaeus, 1766)	2, 8
178	Coraciiformes	Meropidae	*Merops leschenaulti* (Vieillot, 1817)	P, 1, 2, 4, 8
179	Coraciiformes	Meropidae	*Merops orientalis* (Latham, 1802)	1, 2, 4, 8
180	Coraciiformes	Meropidae	*Merops philippinus* (Linnaeus, 1766)	1, 2, 8
181	Coraciiformes	Meropidae	*Nyctyornis athertoni* (Jardine & Selby, 1830)	1, 2, 4, 8
182	Cuculiformes	Cuculidae	*Cacomantis merulinus* (Scopoli, 1786)	1, 2, 8
183	Cuculiformes	Cuculidae	*Cacomantis passerinus* (Vahl, 1797)	2
184	Cuculiformes	Cuculidae	*Cacomantis sonneratii* (Latham, 1790)	2, 8
185	Cuculiformes	Cuculidae	*Centropus bengalensis* (Gmelin, 1788)	P, 2, 4, 8
186	Cuculiformes	Cuculidae	*Centropus sinensis* (Stephens, 1815)	P, 2, 4, 8
187	Cuculiformes	Cuculidae	*Chrysococcyx maculatus* (Gmelin, 1788)	2, 8
188	Cuculiformes	Cuculidae	*Chrysococcyx xanthorhynchus* (Horsfield, 1821)	8
189	Cuculiformes	Cuculidae	*Clamator coromandus* (Linnaeus, 1766)	2, 8
190	Cuculiformes	Cuculidae	*Clamator jacobinus* (Boddaert, 1783)	2, 8
191	Cuculiformes	Cuculidae	*Cuculus canorus* (Linnaeus, 1758)	8
192	Cuculiformes	Cuculidae	*Cuculus micropterus* (Gould, 1837)	1, 2, 8
193	Cuculiformes	Cuculidae	*Eudynamys scolopaceus* (Linnaeus, 1758)	P, 1, 2, 8
194	Cuculiformes	Cuculidae	*Hierococcyx nisicolor* (Blyth, 1843)	8
195	Cuculiformes	Cuculidae	*Hierococcyx sparverioides* (Vigors, 1831)	2, 8
196	Cuculiformes	Cuculidae	*Hierococcyx varius* (Vahl, 1797)	1, 2, 8
197	Cuculiformes	Cuculidae	*Phaenicophaeus tristis* (Lesson, 1830)	P, 1, 2, 4, 8
198	Cuculiformes	Cuculidae	*Surniculus lugubris* (Horsfield, 1821)	2, 8
199	Falconiformes	Falconidae	*Falco amurensis* (Radde, 1863)	2, 8
200	Falconiformes	Falconidae	*Falco chicquera* (Daudin, 1800)	2, 8
201	Falconiformes	Falconidae	*Falco jugger* (Gray, 1834)	2, 8
202	Falconiformes	Falconidae	*Falco naumanni* (Fleischer, 1818)	P, 2, 8
203	Falconiformes	Falconidae	*Falco peregrinus* (Tunstall, 1771)	2, 4, 8
204	Falconiformes	Falconidae	*Falco severus* (Horsfield, 1821)	2, 8
205	Falconiformes	Falconidae	*Falco subbuteo* (Linnaeus, 1758)	8
206	Falconiformes	Falconidae	*Falco tinnunculus* (Linnaeus, 1758)	P, 1, 2, 4, 8
207	Falconiformes	Falconidae	*Microhierax melanoleucos* (Blyth, 1843)	P, 2, 8
208	Galliformes	Phasianidae	*Arborophila atrogularis* (Blyth, 1850)	2, 8
209	Galliformes	Phasianidae	*Francolinus gularis* (Temminck, 1815)	P, 1, 2, 4, 8
210	Galliformes	Phasianidae	*Gallus gallus* (Linnaeus, 1758)	P, 1, 2, 4, 8
211	Galliformes	Phasianidae	*Lophura leucomelanos* (Latham, 1790)	P, 1, 2, 8
212	Galliformes	Phasianidae	*Polyplectron bicalcaratum* (Linnaeus, 1758)	2, 8
213	Galliformes	Phasianidae	*Synoicus chinensis* (Linnaeus, 1766)	2, 8
214	Gruiformes	Rallidae	*Amaurornis phoenicurus* (Pennant, 1769)	P, 1, 2, 4, 8
215	Gruiformes	Rallidae	*Fulica atra* (Linnaeus, 1758)	2, 4, 8
216	Gruiformes	Rallidae	*Gallicrex cinerea* (Gmelin, 1789)	1, 2, 4, 8
217	Gruiformes	Rallidae	*Gallinula chloropus* (Linnaeus, 1758)	1, 2, 4, 8
218	Gruiformes	Rallidae	*Lewinia striata* (Linnaeus, 1766)	2, 8
219	Gruiformes	Rallidae	*Porphyrio porphyrio* (Linnaeus, 1758)	P, 1, 2, 8
220	Gruiformes	Rallidae	*Rallina eurizonoides* (Lafresnaye, 1845)	1, 2, 8
221	Gruiformes	Rallidae	*Rallus indicus* (Blyth, 1849)	2, 4, 8
222	Gruiformes	Rallidae	*Zapornia akool* (Sykes, 1832)	1, 2, 8
223	Gruiformes	Rallidae	*Zapornia fusca* (Linnaeus, 1766)	1, 2, 8
224	Otidiformes	Otididae	*Houbaropsis bengalensis* (Gmelin, 1789)	P, 1, 2, 8
225	Passeriformes	Acrocephalidae	*Acrocephalus agricola* (Jerdon, 1845)	P, 2, 8
226	Passeriformes	Acrocephalidae	*Acrocephalus concinens* (Swinhoe, 1870)	2, 8
227	Passeriformes	Acrocephalidae	*Acrocephalus dumetorum* (Blyth, 1849)	2, 8
228	Passeriformes	Acrocephalidae	*Acrocephalus stentoreus* (Ehrenberg, 1833)	2, 8
229	Passeriformes	Acrocephalidae	*Arundinax aedon* (Pallas, 1776)	2, 8
230	Passeriformes	Aegithinidae	*Aegithina tiphia* (Linnaeus, 1758)	1, 2, 4, 8
231	Passeriformes	Alaudidae	*Alauda gulgula* (Franklin, 1831)	2, 8
232	Passeriformes	Alaudidae	*Alaudala raytal* (Blyth, 1844)	1, 2, 8

S.No.	Order	Family	Scientific name (IUCN)	Literature
233	Passeriformes	Alaudidae	*Mirafra assamica* (Horsfield, 1840)	1, 2, 8
234	Passeriformes	Alaudidae	Mirafra cantillans (Blyth, 1844)	2
235	Passeriformes	Alaudidae	*Mirafra erythroptera* Blyth, 1845	1
236	Passeriformes	Artamidae	*Artamus fuscus* (Vieillot, 1817)	2, 4, 8
237	Passeriformes	Campephagidae	*Coracina macei* (Lesson, 1831)	1, 2, 4, 8
238	Passeriformes	Campephagidae	*Lalage melaschistos* (Hodgson, 1836)	1, 2, 4, 8
239	Passeriformes	Campephagidae	*Pericrocotus brevirostris* (Vigors, 1831)	1, 2, 4, 8
240	Passeriformes	Campephagidae	*Pericrocotus cinnamomeus* (Linnaeus, 1766)	1, 2, 8
241	Passeriformes	Campephagidae	*Pericrocotus ethologus* (Bangs & Phillips, 1914)	2, 4, 8
242	Passeriformes	Campephagidae	*Pericrocotus flammeus* (Forster, 1781)	P, 1, 2, 4, 8
243	Passeriformes	Campephagidae	*Pericrocotus roseus* (Vieillot, 1818)	8
244	Passeriformes	Campephagidae	*Pericrocotus solaris* (Blyth, 1846)	2, 8
245	Passeriformes	Chloropseidae	*Chloropsis aurifrons* (Temminck, 1829)	1, 2, 4, 8
246	Passeriformes	Chloropseidae	*Chloropsis cochinchinensis* (Gmelin, 1789)	1, 2, 8
247	Passeriformes	Chloropseidae	*Chloropsis hardwickii* (Jardine & Selby, 1830)	8
248	Passeriformes	Cisticolidae	*Cisticola exilis* (Vigors & Horsfield, 1827)	2, 8
249	Passeriformes	Cisticolidae	*Cisticola juncidis* (Rafinesque, 1810)	2, 4, 8
250	Passeriformes	Cisticolidae	*Orthotomus atrogularis* (Temminck, 1836)	2, 8
251	Passeriformes	Cisticolidae	*Orthotomus sutorius* (Pennant, 1769)	2, 4, 8
252	Passeriformes	Cisticolidae	*Prinia crinigera* (Hodgson, 1836)	8
253	Passeriformes	Cisticolidae	*Prinia flaviventris* (Delessert, 1840)	2, 8
254	Passeriformes	Cisticolidae	*Prinia gracilis* (Lichtenstein, 1823)	2, 8
255	Passeriformes	Cisticolidae	*Prinia hodgsonii* (Blyth, 1844)	2, 8
256	Passeriformes	Cisticolidae	*Prinia inornata* (Sykes, 1832)	2, 4, 8
257	Passeriformes	Cisticolidae	*Prinia socialis* (Sykes, 1832)	P, 2, 4, 8
258	Passeriformes	Corvidae	*Cissa chinensis* (Boddaert, 1783)	1, 2, 4, 8
259	Passeriformes	Corvidae	*Corvus macrorhynchos* (Wagler, 1827)	P, 1, 2, 4, 8
260	Passeriformes	Corvidae	*Corvus splendens* (Vieillot, 1817)	P, 1, 2, 4, 8
261	Passeriformes	Corvidae	*Dendrocitta formosae* (Swinhoe, 1863)	2, 8
262	Passeriformes	Corvidae	*Dendrocitta vagabunda* (Latham, 1790)	P, 1, 2, 4, 8
263	Passeriformes	Dicaeidae	*Dicaeum agile* (Tickell, 1833)	2, 8
264	Passeriformes	Dicaeidae	*Dicaeum chrysorrheum* (Temminck & Laugier, 1829)	2, 8
265	Passeriformes	Dicaeidae	*Dicaeum concolor* (Jerdon, 1840)	2, 8
266	Passeriformes	Dicaeidae	*Dicaeum cruentatum* (Linnaeus, 1758)	1, 2, 4, 8
267	Passeriformes	Dicaeidae	*Dicaeum erythrorhynchos* (Latham, 1790)	2, 8
268	Passeriformes	Dicaeidae	*Dicaeum ignipectus* (Blyth, 1843)	1, 8
269	Passeriformes	Dicruridae	*Dicrurus aeneus* (Vieillot, 1817)	1, 2, 4, 8
270	Passeriformes	Dicruridae	*Dicrurus annectens* (Hodgson, 1836)	1, 2, 8
271	Passeriformes	Dicruridae	*Dicrurus hottentottus* (Linnaeus, 1766)	1, 2, 4, 8
272	Passeriformes	Dicruridae	*Dicrurus leucophaeus* (Vieillot, 1817)	P, 2, 4, 8
273	Passeriformes	Dicruridae	*Dicrurus macrocercus* (Vieillot, 1817)	P, 1, 2, 4, 8
274	Passeriformes	Dicruridae	*Dicrurus paradiseus* (Linnaeus, 1766)	P, 2, 4, 8
275	Passeriformes	Dicruridae	*Dicrurus remifer* (Temminck, 1823)	P, 1, 2, 4, 8
276	Passeriformes	Emberizidae	*Emberiza aureola* (Pallas, 1773)	2, 8
277	Passeriformes	Emberizidae	*Emberiza pusilla* (Pallas, 1776)	1, 2, 8
278	Passeriformes	Emberizidae	*Emberiza spodocephala* (Pallas, 1776)	2, 8
279	Passeriformes	Estrildidae	*Amandava amandava* (Linnaeus, 1758)	2, 8
280	Passeriformes	Estrildidae	*Euodice malabarica* (Linnaeus, 1758)	1
281	Passeriformes	Estrildidae	*Lonchura atricapilla* (Vieillot, 1807)	8
282	Passeriformes	Estrildidae	*Lonchura malacca* (Linnaeus, 1766)	1, 2, 8
283	Passeriformes	Estrildidae	*Lonchura punctulata* (Linnaeus, 1758)	P, 1, 2, 4, 8
284	Passeriformes	Estrildidae	*Lonchura striata* (Linnaus, 1766)	1, 2, 8
285	Passeriformes	Eurylaimidae	*Psarisomus dalhousiae* (Jameson, 1835)	8
286	Passeriformes	Eurylaimidae	*Serilophus lunatus* (Gould, 1834)	2, 8
287	Passeriformes	Hirundinidae	*Cecropis daurica* (Linnaeus, 1771)	1, 2, 4, 8
288	Passeriformes	Hirundinidae	*Cecropis striolata* (Schlegel, 1844)	2, 8
289	Passeriformes	Hirundinidae	*Delichon nipalense* (Horsfield & Moore, 1854)	8
290	Passeriformes	Hirundinidae	*Hirundo rustica* (Linnaeus, 1758)	P, 1, 2, 4, 8
291	Passeriformes	Hirundinidae	*Riparia chinensis* (Gray, 1830)	8
292	Passeriformes	Hirundinidae	*Riparia diluta* (Sharpe & Wyatt, 1893)	2, 8
293	Passeriformes	Hirundinidae	*Riparia paludicola* (Vieillot, 1817)	1, 2, 4
294	Passeriformes	Hirundinidae	*Riparia riparia* (Linnaeus, 1758)	2, 8
295	Passeriformes	Irenidae	*Irena puella* (Latham, 1790)	2, 4, 8
296	Passeriformes	Laniidae	*Lanius cristatus* (Linnaeus, 1758)	1, 2, 4, 8
297	Passeriformes	Laniidae	*Lanius schach* (Linnaeus, 1758)	P, 1, 2, 4, 8
298	Passeriformes	Laniidae	*Lanius tephronotus* (Vigors, 1831)	P, 1, 2, 4, 8
299	Passeriformes	Leiotrichidae	*Alcippe poioicephala* (Jerdon, 1844)	2, 8

S.No.	Order	Family	Scientific name (IUCN)	Literature
300	Passeriformes	Leiotrichidae	*Argya earlei* (Blyth, 1844)	1, 2, 4, 8
301	Passeriformes	Leiotrichidae	*Argya longirostris* (Moore, 1854)	2, 8
302	Passeriformes	Leiotrichidae	*Garrulax leucolophus* (Hardwicke, 1815)	1, 2, 4, 8
303	Passeriformes	Leiotrichidae	*Garrulax monileger* (Riley, 1930)	1, 2, 4, 8
304	Passeriformes	Leiotrichidae	*Garrulax pectoralis* (Gould, 1836)	2, 4, 8
305	Passeriformes	Leiotrichidae	*Garrulax ruficollis* (Jardine & Selby, 1838)	1, 2, 4, 8
306	Passeriformes	Leiotrichidae	*Garrulax rufogularis* (Gould, 1835)	8
307	Passeriformes	Leiotrichidae	*Argya striata* (Dumont, 1823)	P, 1, 2, 8
308	Passeriformes	Locustellidae	*Schoenicola striata* (Jerdon, 1841)	2, 8
309	Passeriformes	Locustellidae	*Helopsaltes certhiola* (Pallas, 1811)	2
310	Passeriformes	Locustellidae	*Locustella mandelli* (W.E. Brooks, 1875)	8
311	Passeriformes	Locustellidae	*Locustella tacsanowskia* (Swinhoe, 1871)	2, 8
312	Passeriformes	Locustellidae	*Locustella thoracica* (Blyth, 1845)	2, 8
313	Passeriformes	Locustellidae	*Megalurus palustris* (Horsfield, 1821)	P, 2, 4, 8
314	Passeriformes	Monarchidae	*Hypothymis azurea* (Boddaert, 1783)	2, 4, 8
315	Passeriformes	Monarchidae	*Terpsiphone paradisi* (Linnaeus, 1758)	2, 8
316	Passeriformes	Motacillidae	*Anthus campestris* (Linnaeus, 1758)	8
317	Passeriformes	Motacillidae	*Anthus godlewskii* (Taczanowski, 1876)	2, 8
318	Passeriformes	Motacillidae	*Anthus hodgsoni* (Richmond, 1907)	2, 4, 8
319	Passeriformes	Motacillidae	*Anthus richardi* (Vieillot, 1818)	2, 8
320	Passeriformes	Motacillidae	*Anthus roseatus* (Blyth, 1847)	P, 2, 4, 8
321	Passeriformes	Motacillidae	*Anthus rufulus* (Vieillot, 1818)	P, 2, 4, 8
322	Passeriformes	Motacillidae	*Dendronanthus indicus* (Gmelin, 1789)	2, 8
323	Passeriformes	Motacillidae	*Motacilla alba* (Linnaeus, 1758)	P, 1, 2, 4, 8
324	Passeriformes	Motacillidae	*Motacilla cinerea* (Tunstall, 1771)	1, 2, 4, 8
325	Passeriformes	Motacillidae	*Motacilla citreola* (Pallas, 1776)	P, 1, 2, 4, 8
326	Passeriformes	Motacillidae	*Motacilla flava* (Linnaeus, 1758)	P, 1, 2, 4, 8
327	Passeriformes	Motacillidae	*Motacilla maderaspatensis* (Gmelin, 1789)	1, 2, 8
328	Passeriformes	Muscicapidae	*Brachypteryx leucophris* (Temminck, 1827)	2, 8
329	Passeriformes	Muscicapidae	*Calliope calliope* (Pallas, 1776)	2, 4, 8
330	Passeriformes	Muscicapidae	*Calliope pectoralis* (Gould, 1837)	2, 8
331	Passeriformes	Muscicapidae	*Copsychus saularis* (Linnaeus, 1758)	P, 2, 4, 8
332	Passeriformes	Muscicapidae	*Cyanecula svecica* (Linnaeus, 1758)	P, 2, 8
333	Passeriformes	Muscicapidae	*Cyornis poliogenys* (Brooks, 1879)	2, 8
334	Passeriformes	Muscicapidae	*Cyornis unicolor* (Blyth, 1843)	8
335	Passeriformes	Muscicapidae	*Enicurus immaculatus* (Hodgson, 1836)	2, 4, 8
336	Passeriformes	Muscicapidae	*Enicurus leschenaulti* (Vieillot, 1818)	2, 8
337	Passeriformes	Muscicapidae	*Eumyias thalassinus* (Swainson, 1838)	1, 2, 4, 8
338	Passeriformes	Muscicapidae	*Ficedula albicilla* (Pallas, 1811)	2, 4, 8
339	Passeriformes	Muscicapidae	*Ficedula erithacus* (Jerdon and Blyth, 1861)	2, 8
340	Passeriformes	Muscicapidae	*Ficedula hodgsoni* (Moore, 1854)	2, 8
341	Passeriformes	Muscicapidae	*Ficedula hyperythra* (Blyth, 1843)	2, 8
342	Passeriformes	Muscicapidae	*Ficedula parva* (Bechstein, 1792)	1
343	Passeriformes	Muscicapidae	*Ficedula strophiata* (Hodgson, 1837)	8
344	Passeriformes	Muscicapidae	*Ficedula tricolor* (Hodgson, 1845)	2, 8
345	Passeriformes	Muscicapidae	*Ficedula westermanni* (Sharpe, 1888)	2, 4, 8
346	Passeriformes	Muscicapidae	*Kittacincla malabarica* (Scopoli, 1788)	2, 4, 8
347	Passeriformes	Muscicapidae	*Monticola solitarius* (Linnaeus, 1758)	1, 2, 4
348	Passeriformes	Muscicapidae	*Muscicapa dauurica* Pallas, 1811	2
349	Passeriformes	Muscicapidae	*Muscicapa ferruginea* (Hodgson, 1845)	2
350	Passeriformes	Muscicapidae	*Muscicapa sibirica* (Gmelin, 1789)	2, 8
351	Passeriformes	Muscicapidae	*Myiomela leucura* (Hodgson, 1845)	2
352	Passeriformes	Muscicapidae	*Myophonus caeruleus* (Scopoli, 1786)	P, 1, 2, 4, 8
353	Passeriformes	Muscicapidae	*Niltava grandis* (Blyth, 1842)	2, 4, 8
354	Passeriformes	Muscicapidae	*Niltava macgrigoriae* (Burton, 1836)	2, 4, 8
355	Passeriformes	Muscicapidae	*Niltava sundara* (Hodgson, 1837)	8
356	Passeriformes	Muscicapidae	*Phoenicurus auroreus* (Pallas, 1776)	2, 4, 8
357	Passeriformes	Muscicapidae	*Phoenicurus fuliginosus* (Vigors, 1831)	2, 8
358	Passeriformes	Muscicapidae	*Phoenicurus leucocephalus* (Vigors, 1831)	2, 8
359	Passeriformes	Muscicapidae	*Phoenicurus ochruros* (Gmelin, 1774)	2, 8
360	Passeriformes	Muscicapidae	*Saxicola caprata* (Linnaeus, 1766)	8
361	Passeriformes	Muscicapidae	*Saxicola ferreus* (Gray, 1846)	2, 8
362	Passeriformes	Muscicapidae	*Saxicola insignis* (Gray, 1846)	P, 2, 8
363	Passeriformes	Muscicapidae	*Saxicola jerdoni* (Blyth, 1867)	2, 8
364	Passeriformes	Muscicapidae	*Saxicola leucurus* (Blyth, 1847)	2, 8
365	Passeriformes	Muscicapidae	*Saxicola maurus* (Pallas, 1773)	8
366	Passeriformes	Muscicapidae	*Saxicola torquatus* (Linnaeus, 1766)	P, 2, 4, 8

S.No.	Order	Family	Scientific name (IUCN)	Literature
367	Passeriformes	Nectariniidae	*Aethopyga gouldiae* (Vigors, 1831)	2, 8
368	Passeriformes	Nectariniidae	*Aethopyga nipalensis* (Hodgson, 1837)	8
369	Passeriformes	Nectariniidae	*Aethopyga saturata* (Hodgson, 1836)	2, 8
370	Passeriformes	Nectariniidae	*Aethopyga siparaja* (Raffles, 1822)	P, 1, 2, 4, 8
371	Passeriformes	Nectariniidae	*Arachnothera longirostra* (Latham, 1790)	1, 2, 4, 8
372	Passeriformes	Nectariniidae	*Arachnothera magna* (Hodgson, 1837)	1, 2, 8
373	Passeriformes	Nectariniidae	*Chalcoparia singalensis* (Gmelin, 1789)	1, 2, 4
374	Passeriformes	Nectariniidae	*Cinnyris asiaticus* (Latham, 1790)	P, 1, 2, 8
375	Passeriformes	Oriolidae	*Oriolus chinensis* (Linnaeus, 1766)	8
376	Passeriformes	Oriolidae	*Oriolus tenuirostris* (Blyth, 1846)	2
377	Passeriformes	Oriolidae	*Oriolus traillii* (Vigors, 1832)	2, 4, 8
378	Passeriformes	Oriolidae	*Oriolus xanthornus* (Linnaeus, 1758)	1, 2, 4, 8
379	Passeriformes	Paridae	*Melanochlora sultanea* (Hodgson, 1837)	2, 8
380	Passeriformes	Paridae	*Parus cinereus (*Vieillot, 1818)	8
381	Passeriformes	Paridae	*Parus major* (Linnaeus, 1758)	P, 2, 4
382	Passeriformes	Passerellidae	*Peucaea sumichrasti* (Lawrence, 1871)	8
383	Passeriformes	Passeridae	*Passer domesticus* (Linnaeus, 1758)	P, 1, 2, 4, 8
384	Passeriformes	Passeridae	*Passer montanus* (Linnaeus, 1758)	1, 2, 4, 8
385	Passeriformes	Passeridae	*Passer rutilans* (Temminck, 1836)	8
386	Passeriformes	Pellorneidae	*Gampsorhynchus rufulus* (Blyth, 1844)	2, 8
387	Passeriformes	Pellorneidae	*Graminicola bengalensis* (Jerdon, 1863)	2, 8
388	Passeriformes	Pellorneidae	*Laticilla burnesii* (Blyth, 1844)	2, 8
389	Passeriformes	Pellorneidae	*Laticilla cinerascens* (Walden, 1874)	8
390	Passeriformes	Pellorneidae	*Malacocincla abbotti* (Blyth, 1845)	2, 4, 8
391	Passeriformes	Pellorneidae	*Napothera epilepidota* (Temminck, 1827)	4
392	Passeriformes	Pellorneidae	*Pellorneum palustre* (Gould, 1872)	2, 8
393	Passeriformes	Pellorneidae	*Pellorneum ruficeps* (Swainson, 1832)	1, 2, 4, 8
394	Passeriformes	Pellorneidae	*Pellorneum tickelli* (Blyth, 1859)	8
395	Passeriformes	Phylloscopidae	*Phylloscopus affinis* (Tickell, 1833)	2, 4, 8
396	Passeriformes	Phylloscopidae	*Phylloscopus burkii* (E. Burton, 1836)	2, 8
397	Passeriformes	Phylloscopidae	*Phylloscopus cantator* (Tickell, 1833)	2, 8
398	Passeriformes	Phylloscopidae	*Phylloscopus castaniceps* (Hodgson, 1845)	2, 8
399	Passeriformes	Phylloscopidae	*Phylloscopus chloronotus* (Gray & Gray, 1846)	2, 8
400	Passeriformes	Phylloscopidae	*Phylloscopus collybita* (Vieillot, 1817)	2, 8
401	Passeriformes	Phylloscopidae	*Phylloscopus coronatus* (Temminck & Schlegel, 1847)	2
402	Passeriformes	Phylloscopidae	*Phylloscopus fuligiventer* (Hodgson, 1845)	2, 8
403	Passeriformes	Phylloscopidae	*Phylloscopus fuscatus* (Blyth, 1842)	2, 4, 8
404	Passeriformes	Phylloscopidae	*Phylloscopus inornatus* (Blyth, 1842)	2, 4, 8
405	Passeriformes	Phylloscopidae	*Phylloscopus intermedius* (La Touche, 1898)	2, 8
406	Passeriformes	Phylloscopidae	*Phylloscopus magnirostris* (Blyth, 1843)	2, 8
407	Passeriformes	Phylloscopidae	*Phylloscopus poliogenys* (Blyth, 1847)	2, 8
408	Passeriformes	Phylloscopidae	*Phylloscopus reguloides* (Blyth, 1842)	2, 4, 8
409	Passeriformes	Phylloscopidae	*Phylloscopus trochiloides* (Sundevall, 1837)	2, 4, 8
410	Passeriformes	Phylloscopidae	*Phylloscopus whistleri* (Ticehurst, 1925)	8
411	Passeriformes	Phylloscopidae	*Phylloscopus xanthoschistos* (Gray, 1846)	2, 8
412	Passeriformes	Pittidae	*Hydrornis cyaneus* (Blyth, 1843)	2, 8
413	Passeriformes	Pittidae	*Hydrornis nipalensis* (Hodgson, 1837)	1, 2, 4, 8
414	Passeriformes	Pittidae	*Hydrornis oatesi* (Hume, 1873)	1
415	Passeriformes	Pittidae	*Pitta brachyura* (Linnaeus, 1766)	2, 8
416	Passeriformes	Pittidae	*Pitta sordida* (Müller, 1776)	5, 8
417	Passeriformes	Ploceidae	*Ploceus benghalensis* (Linnaeus, 1758)	1, 2, 8
418	Passeriformes	Ploceidae	*Ploceus manyar* (Horsfield, 1821)	1, 2, 8
419	Passeriformes	Ploceidae	*Ploceus megarhynchus* (Hume, 1869)	2, 4, 8
420	Passeriformes	Ploceidae	*Ploceus philippinus* (Linnaeus, 1766)	1, 2, 4, 8
421	Passeriformes	Pnoepygidae	*Pnoepyga pusilla* (Hodgson, 1845)	2, 8
422	Passeriformes	Pycnonotidae	*Alophoixus flaveolus* (Gould, 1836)	1, 2, 4, 8
423	Passeriformes	Pycnonotidae	*Brachypodius atriceps* (Temminck, 1822)	1, 8
424	Passeriformes	Pycnonotidae	*Hemixos flavala* (Blyth, 1845)	2, 8
425	Passeriformes	Pycnonotidae	*Hypsipetes leucocephalus* (Gmelin, 1789)	1, 2, 8
426	Passeriformes	Pycnonotidae	*Pycnonotus cafer* (Linnaeus, 1766)	P, 1, 2, 4, 8
427	Passeriformes	Pycnonotidae	*Pycnonotus flavescens* (Blyth, 1845)	8
428	Passeriformes	Pycnonotidae	*Rubigula flaviventris* (Tickell, 1833)	4, 8
429	Passeriformes	Pycnonotidae	*Pycnonotus jocosus* (Linnaeus, 1758)	1, 2, 4, 8
430	Passeriformes	Pycnonotidae	*Rubigula melanictera* (Gmelin, 1789)	2
431	Passeriformes	Rhipiduridae	*Rhipidura albicollis* (Vieillot, 1818)	2, 8
432	Passeriformes	Rhipiduridae	*Rhipidura aureola* (Lesson, 1830)	2
433	Passeriformes	Scotocercidae	*Abroscopus superciliaris* (Blyth, 1859)	2, 8

S.No.	Order	Family	Scientific name (IUCN)	Literature
434	Passeriformes	Scotocercidae	*Cettia brunnifrons* (Hodgson, 1845)	2, 8
435	Passeriformes	Scotocercidae	*Cettia castaneocoronata* (Burton, 1836)	2, 8
436	Passeriformes	Scotocercidae	*Cettia major* (Horsfield & Moore, 1854)	2, 8
437	Passeriformes	Scotocercidae	*Hemitesia pallidipes* (Blanford, 1872)	2, 8
438	Passeriformes	Scotocercidae	*Horornis fortipes* (Hodgson, 1845)	2, 8
439	Passeriformes	Scotocercidae	*Phyllergates cucullatus* (Temminck, 1836)	2, 8
440	Passeriformes	Scotocercidae	*Tesia cyaniventer* (Hodgson, 1837)	2, 4, 8
441	Passeriformes	Scotocercidae	*Tesia olivea* (McClelland, 1840)	2, 8
442	Passeriformes	Sittidae	*Sitta castanea* (Lesson, 1830)	2, 4
443	Passeriformes	Sittidae	*Sitta cinnamoventris* (Blyth, 1842)	8
444	Passeriformes	Sittidae	*Sitta frontalis* (Swainson, 1820)	2, 4, 8
445	Passeriformes	Sittidae	*Tichodroma muraria* (Linnaeus, 1766)	2, 8
446	Passeriformes	Stenostiridae	*Chelidorhynx hypoxanthus* (Blyth, 1843)	2, 8
447	Passeriformes	Stenostiridae	*Culicicapa ceylonensis* (Swainson, 1820)	2, 4, 8
448	Passeriformes	Sturnidae	*Acridotheres cinereus* (Bonaparte, 1851)	2
449	Passeriformes	Sturnidae	*Acridotheres fuscus* (Wagler, 1827)	P, 1, 2, 4, 8
450	Passeriformes	Sturnidae	*Acridotheres ginginianus* (Latham, 1790)	P, 1, 2, 8
451	Passeriformes	Sturnidae	*Acridotheres grandis* Moore, 1858	P, 4, 8
452	Passeriformes	Sturnidae	*Acridotheres tristis* (Linnaeus, 1766)	P, 1, 2, 4, 8
453	Passeriformes	Sturnidae	*Gracula religiosa* (Linnaeus, 1758)	P, 1, 2, 4, 8
454	Passeriformes	Sturnidae	*Gracupica contra* (Linnaeus, 1758)	P, 1, 2, 4, 8
455	Passeriformes	Sturnidae	*Saroglossa spilopterus* (Vigors, 1831)	1, 2, 8
456	Passeriformes	Sturnidae	*Sturnia malabarica* (Gmelin, 1789)	1, 2, 4, 8
457	Passeriformes	Sturnidae	*Sturnia pagodarum* (Gmelin, 1789)	P, 2, 8
458	Passeriformes	Paradoxornithidae	*Chrysomma altirostre* (Jerdon, 1862)	2, 8
459	Passeriformes	Paradoxornithidae	*Chrysomma sinense* (Gmelin, 1789)	1, 2, 8
460	Passeriformes	Paradoxornithidae	*Paradoxornis flavirostris* (Gould, 1836)	2, 4, 8
461	Passeriformes	Sylviidae	*Curruca curruca* (Linnaeus, 1758)	2, 8
462	Passeriformes	Timaliidae	*Cyanoderma chrysaeum* (Blyth, 1844)	2, 8
463	Passeriformes	Timaliidae	*Cyanoderma ruficeps* (Blyth, 1847)	2
464	Passeriformes	Timaliidae	*Cyanoderma rufifrons* (Hume, 1873)	1, 2, 8
465	Passeriformes	Timaliidae	*Erythrogenys hypoleucos* (Blyth, 1844)	2, 8
466	Passeriformes	Timaliidae	*Mixornis gularis* (Horsfield, 1822)	1, 2, 4, 8
467	Passeriformes	Timaliidae	*Pomatorhinus schisticeps* (Hodgson, 1836)	2, 4, 8
468	Passeriformes	Timaliidae	*Stachyris nigriceps* (Blyth, 1844)	1, 2, 8
469	Passeriformes	Timaliidae	*Timalia pileata* (Horsfield, 1821)	P, 1, 2, 8
470	Passeriformes	Turdidae	*Cochoa viridis* (Hodgson, 1836)	8
471	Passeriformes	Turdidae	*Geokichla citrina* (Latham, 1790)	2, 4, 8
472	Passeriformes	Turdidae	*Turdus boulboul* (Latham, 1790)	2, 8
473	Passeriformes	Turdidae	*Turdus dissimilis* (Blyth, 1847)	2
474	Passeriformes	Turdidae	*Turdus ruficollis* (Pallas, 1776)	2
475	Passeriformes	Turdidae	*Zoothera dauma* (Latham, 1790)	2, 8
476	Passeriformes	Turdidae	*Zoothera dixoni* (Seebohm, 1881)	2
477	Passeriformes	Vangidae	*Hemipus picatus* (Sykes, 1832)	2
478	Passeriformes	Vangidae	*Tephrodornis pondicerianus* (Gmelin, 1789)	1, 2, 8
479	Passeriformes	Vangidae	*Tephrodornis virgatus* (Temminck, 1824)	2, 8
480	Passeriformes	Vireonidae	*Erpornis zantholeuca* (Blyth, 1844)	2, 8
481	Passeriformes	Zosteropidae	*Yuhina nigrimenta* (Blyth, 1845)	8
482	Passeriformes	Zosteropidae	*Zosterops palpebrosus* (Temminck, 1824)	1, 2, 4, 8
483	Pelecaniformes	Ardeidae	*Ardea alba* (Linnaeus, 1758)	P, 1, 2, 4, 8
484	Pelecaniformes	Ardeidae	*Ardea cinerea* (Linnaeus, 1758)	P, 1, 2, 4, 8
485	Pelecaniformes	Ardeidae	*Ardea goliath* (Cretzschmar, 1827)	2, 8
486	Pelecaniformes	Ardeidae	*Ardea insignis* (Hume, 1878)	2, 8
487	Pelecaniformes	Ardeidae	*Ardea intermedia* (Wagler, 1829)	P, 1, 2, 4, 8
488	Pelecaniformes	Ardeidae	*Ardea purpurea* (Linnaeus, 1766)	P, 1, 2, 4, 8
489	Pelecaniformes	Ardeidae	*Ardeola bacchus* (Bonaparte, 1855)	P, 2, 4, 8
490	Pelecaniformes	Ardeidae	*Ardeola grayii* (Sykes, 1832)	P, 1, 2, 4, 8
491	Pelecaniformes	Ardeidae	*Botaurus stellaris* (Linnaeus, 1758)	2, 8
492	**Pelecaniformes**	**Ardeidae**	*Bubulcus coromandus* (Boddaert, 1783)	**4, 8**
493	Pelecaniformes	Ardeidae	*Bubulcus ibis* (Linnaeus, 1758)	P, 1, 2
494	Pelecaniformes	Ardeidae	*Butorides striata* (Linnaeus, 1758)	1, 2, 8
495	Pelecaniformes	Ardeidae	*Egretta garzetta* (Linnaeus, 1766)	P, 1, 2, 4, 8
496	Pelecaniformes	Ardeidae	*Gorsachius melanolophus* (Raffles, 1822)	2, 8
497	Pelecaniformes	Ardeidae	*Ixobrychus cinnamomeus* (Gmelin, 1789)	1, 2, 8
498	Pelecaniformes	Ardeidae	*Ixobrychus flavicollis* (Latham, 1790)	1, 2, 8
499	Pelecaniformes	Ardeidae	*Ixobrychus minutus* (Linnaeus, 1766)	2
500	Pelecaniformes	Ardeidae	*Ixobrychus sinensis* (Gmelin, 1789)	1, 2, 8

S.No.	Order	Family	Scientific name (IUCN)	Literature
501	Pelecaniformes	Ardeidae	*Nycticorax nycticorax* (Linnaeus, 1758)	1, 2, 8
502	Pelecaniformes	Pelecanidae	*Pelecanus crispus* (Bruch, 1832)	2, 8
503	Pelecaniformes	Pelecanidae	*Pelecanus onocrotalus* (Linnaeus, 1758)	2, 4, 8
504	Pelecaniformes	Pelecanidae	*Pelecanus philippensis* (Gmelin, 1789)	P, 1, 2, 4, 8
505	Pelecaniformes	Threskiornithidae	*Platalea leucorodia* (Linnaeus, 1758)	8
506	Pelecaniformes	Threskiornithidae	*Plegadis falcinellus* (Linnaeus, 1766)	8
507	Pelecaniformes	Threskiornithidae	*Threskiornis melanocephalus* (Latham, 1790)	P, 2, 4, 8
508	Piciformes	Megalaimidae	*Psilopogon asiaticus* (Latham, 1790)	P, 1, 2, 4, 8
509	Piciformes	Megalaimidae	*Psilopogon australis* (Horsfield, 1821)	1, 2, 4, 8
510	Piciformes	Megalaimidae	*Psilopogon haemacephalus* (Müller, 1776)	2, 4, 8
511	Piciformes	Megalaimidae	*Psilopogon lineatus* (Vieillot, 1816)	P, 1, 2, 4, 8
512	Piciformes	Megalaimidae	*Psilopogon virens* (Boddaert, 1783)	8
513	Piciformes	Picidae	*Blythipicus pyrrhotis* (Hodgson, 1837)	2, 8
514	Piciformes	Picidae	*Chrysocolaptes guttacristatus* (Tickell, 1833)	P, 2, 8
515	Piciformes	Picidae	*Chrysocolaptes lucidus* (Scopoli, 1786)	1, 4
516	Piciformes	Picidae	*Chrysophlegma flavinucha* (Gould, 1834)	2, 4, 8
517	Piciformes	Picidae	*Dendrocopos macei* (Vieillot, 1818)	P, 1, 2, 8
518	Piciformes	Picidae	*Dinopium benghalense* (Linnaeus, 1758)	2, 4, 8
519	Piciformes	Picidae	*Dinopium javanense* (Ljungh, 1797)	P, 2, 8
520	Piciformes	Picidae	*Dinopium shorii* (Vigors, 1832)	P, 1, 2, 8
521	Piciformes	Picidae	*Gecinulus grantia* (McClelland, 1840)	8
522	Piciformes	Picidae	*Jynx torquilla* (Linnaeus, 1758)	1, 2, 8
523	Piciformes	Picidae	*Micropternus brachyurus* (Vieillot, 1818)	2, 4, 8
524	Piciformes	Picidae	*Picoides canicapillus* (Blyth, 1845)	1, 2, 8
525	Piciformes	Picidae	*Picumnus innominatus* (Burton, 1836)	1, 2, 8
526	Piciformes	Picidae	*Picus canus* (Gmelin, 1788)	1, 2, 4, 8
527	Piciformes	Picidae	*Picus chlorolophus* (Vieillot, 1818)	2, 4, 8
528	Piciformes	Picidae	*Picus viridanus* (Blyth, 1843)	1
529	Piciformes	Picidae	*Picus xanthopygaeus* (Gray & Gray, 1846)	P, 1, 2, 4, 8
530	Piciformes	Picidae	*Sasia ochracea* (Hodgson, 1836)	1, 2, 4, 8
531	Podicipediformes	Podicipedidae	*Podiceps cristatus* (Linnaeus, 1758)	2, 8
532	Podicipediformes	Podicipedidae	*Tachybaptus ruficollis* (Pallas, 1764)	2, 8
533	Psittaciformes	Psittacidae	*Loriculus vernalis* (Sparrman, 1787)	8
534	Psittaciformes	Psittacidae	*Psittacula alexandri* (Linnaeus, 1758)	P, 1, 2, 4, 8
535	Psittaciformes	Psittacidae	*Psittacula derbiana* (Fraser, 1852)	6
536	Psittaciformes	Psittacidae	*Palaeornis eupatria* (Linnaeus, 1766)	P, 1, 2, 4, 8
537	Psittaciformes	Psittacidae	*Himalayapsitta finschii* (Hume, 1874)	2, 8
538	Psittaciformes	Psittacidae	*Alexandrinus krameri* (Scopoli, 1769)	P, 1, 2, 4, 8
539	Psittaciformes	Psittacidae	*Himalayapsitta roseata* (Biswas, 1951)	2, 4, 8
540	Strigiformes	Strigidae	*Athene brama* (Temminck, 1821)	1, 2, 4, 8
541	Strigiformes	Strigidae	*Bubo bubo* (Linnaeus, 1758)	1, 2, 8
542	Strigiformes	Strigidae	*Bubo coromandus* (Latham, 1790)	2, 8
543	Strigiformes	Strigidae	*Glaucidium brodiei* (Burton, 1836)	2, 8
544	Strigiformes	Strigidae	*Glaucidium cuculoides* (Vigors, 1831)	P, 2, 4, 8
545	Strigiformes	Strigidae	*Glaucidium radiatum* (Tickell, 1833)	P, 1, 2
546	Strigiformes	Strigidae	*Ketupa flavipes* (Hodgson, 1836)	2, 8
547	Strigiformes	Strigidae	*Ketupa zeylonensis* (Gmelin, 1788)	1, 2, 8
548	Strigiformes	Strigidae	*Ninox scutulata* (Raffles, 1822)	2, 8
549	Strigiformes	Strigidae	*Otus lettia* (Hodgson, 1836)	2, 8
550	Strigiformes	Strigidae	*Otus sunia* (Hodgson, 1836)	2, 8
551	Strigiformes	Strigidae	*Strix leptogrammica* (Temminck, 1831)	8
552	Strigiformes	Tytonidae	*Phodilus badius* (Horsfield, 1821)	3
553	Strigiformes	Tytonidae	*Tyto alba* (Scopoli, 1769)	8
554	Suliformes	Anhingidae	*Anhinga melanogaster* (Pennant, 1769)	P, 2, 4, 8
555	Suliformes	Phalacrocoracidae	*Microcarbo niger* (Vieillot, 1817)	P, 1, 2, 4, 8
556	Suliformes	Phalacrocoracidae	*Microcarbo pygmaeus* (Pallas, 1773)	1
557	Suliformes	Phalacrocoracidae	*Phalacrocorax carbo* (Linnaeus, 1758)	P, 1, 2, 4, 8
558	Suliformes	Phalacrocoracidae	*Phalacrocorax fuscicollis* (Stephens, 1826)	P, 1, 2, 4, 8
559	Trogoniformes	Trogonidae	*Harpactes erythrocephalus* (Gould, 1834)	1, 2, 8

Population- Population trend from IUCN (2022), IUCN status- International Union for Conservation of Nature, NE- Not Evaluated, LC- Least Concern, NT- Near Threatened, VU- Vulnerable, EN- Endangered, CR- Critically Endangered, IWPA- Wild Life (Protection) Act, 1972, CITES- Convention on International Trade in Endangered Species of Wild Fauna and Flora, P- recorded during present study, 1- Pathak (1978), 2- Barua & Sharma (1999), 3- Barman (2005), 4- Baruah (2007), 5- Borthakur & Das (2010), 6- Saikia & Saikia (2015), 7- Choudhary (2014), 8- Rahmani et al. (2016)

Appendix 4. Reptilia diversity in Kaziranga Tiger Reserve, Assam

S.No.	Order	Family	Scientific name (IUCN)	Literature
1	Crocodylia	Gavialidae	*Gavialis gangeticus* (Gmelin in Linnaeus, 1789)	1, 4
2	Squamata	Agamidae	*Calotes emma* (Gray, 1845)	4
3	Squamata	Agamidae	*Calotes maria (*Gray, 1845)	4
4	Squamata	Agamidae	*Calotes versicolor* (Daudin, 1802)	4, 6
5	Squamata	Agamidae	*Ptyctolaemus gularis* (Peters, 1864)	4
6	Squamata	Colubridae	*Ahaetulla nasuta* (Bonnaterre, 1790)	3, 4
7	Squamata	Colubridae	*Ahaetulla prasina* (Boie, 1827)	4
8	Squamata	Colubridae	*Boiga cyanea* (Duméril, Bibron & Duméril, 1854)	4
9	Squamata	Colubridae	*Boiga gokool* (Gray, 1835)	4, 6
10	Squamata	Colubridae	*Boiga quincunciata* (Wall, 1908)	4, 6
11	Squamata	Colubridae	*Chrysopelea ornata* (Shaw, 1802)	4, 6
12	Squamata	Colubridae	*Coelognathus helena* (Daudin, 1803)	4, 6
13	Squamata	Colubridae	*Coelognathus radiatus* (Boie, 1827)	P, 3, 4, 6
14	Squamata	Colubridae	*Dendrelaphis pictus* (Gmelin, 1789)	4, 6
15	Squamata	Colubridae	*Dendrelaphis sp.*	4, 6
16	Squamata	Homalopsidae	*Enhydris enhydris* (Schneider, 1799)	4, 6
17	Squamata	Colubridae	*Lycodon aulicus* (Linnaeus, 1758)	4
18	Squamata	Colubridae	*Lycodon jara* (Shaw, 1802)	4, 6
19	Squamata	Colubridae	*Oligodon arnensis* (Shaw, 1802)	4
20	Squamata	Pseudaspididae	*Psammodynastes pulverulentus* (Boie, 1827)	4
21	Squamata	Colubridae	*Ptyas korros* (Schlegel, 1837)	4, 6
22	Squamata	Colubridae	*Ptyas mucosa* (Linnaeus, 1758)	4, 6
23	Squamata	Elapidae	*Bungarus caeruleus* (Schneider, 1801)	4
24	Squamata	Elapidae	*Bungarus fasciatus* (Schneider, 1801)	4, 6
25	Squamata	Elapidae	*Bungarus niger* (Wall, 1908)	4
26	Squamata	Elapidae	*Naja kaouthia* (Lesson, 1831)	4
27	Squamata	Elapidae	*Ophiophagus hannah* (Cantor, 1836)	P, 4, 6
28	Squamata	Gekkonidae	*Cnemaspis assamensis* (Das & Sengupta, 2000)	4
29	Squamata	Gekkonidae	*Cyrtodactylus khasiensis* (Jerdon, 1870)	4, 6
30	Squamata	Gekkonidae	*Gekko gecko* (Linnaeus, 1758)	4, 6
31	Squamata	Gekkonidae	*Hemidactylus frenatus* (Schlegel in Duméril & Bibron, 1836)	4
32	Squamata	Gekkonidae	*Hemidactylus garnotii* (Duméril & Bibron, 1836)	4
33	Squamata	Gekkonidae	*Hemidactylus karenorum* (Theobald, 1868)	4
34	Squamata	Gekkonidae	*Hemidactylus platyurus* (Schneider, 1797)	4, 6
35	Squamata	Natricidae	*Amphiesma stolatum* (Linnaeus, 1758)	3, 4, 6
36	Squamata	Natricidae	*Hebius xenura* (Wall, 1907)	4
37	Squamata	Natricidae	*Rhabdophis subminiatus* (Schlegel, 1837)	4
38	Squamata	Natricidae	*Trachischium monticola* (Cantor, 1839)	4
39	Squamata	Natricidae	*Xenochrophis flavipunctatus* (Hallowell, 1860)	4
40	Squamata	Natricidae	*Xenochrophis piscator* (Schneider, 1799)	4, 6
41	Squamata	Pythonidae	*Malayopython reticulatus* (Schneider, 1801)	3, 4
42	Squamata	Pythonidae	*Python bivittatus* (Kuhl, 1820)	P, 3, 4, 6
43	Squamata	Scincidae	*Eutropis carinata* (Schneider, 1801)	4
44	Squamata	Scincidae	*Eutropis macularia* (Blyth, 1853)	4
45	Squamata	Scincidae	*Eutropis multifasciata* (Kuhl, 1820)	4, 6
46	Squamata	Scincidae	*Lygosoma albopunctata* (Gray, 1846)	4
47	Squamata	Scincidae	*Lygosoma punctata* (Gmelin, 1799)	4
48	Squamata	Scincidae	*Lygosoma sp.*	6
49	Squamata	Scincidae	*Scincella reevesii* (Gray, 1838)	4
50	Squamata	Scincidae	*Sphenomorphus indicus* (Gray, 1853)	4
51	Squamata	Viperidae	*Cryptelytrops albolabris* (Gray, 1842)	4, 6
52	Squamata	Typhlopidae	*Indotyphlops braminus* (Daudin, 1803)	4
53	Squamata	Typhlopidae	*Indotyphlops jerdoni* (Boulenger, 1890)	4
54	Squamata	Typhlopidae	*Typhlops diardii* (Schlegel, 1839)	4
55	Squamata	Varanidae	*Varanus bengalensis* (Daudin, 1802)	4, 5
56	Squamata	Varanidae	*Varanus flavescens* (Gray, 1827)	4
57	Squamata	Varanidae	*Varanus salvator* (Laurenti, 1768)	4, 5
58	Squamata	Viperidae	*Daboia russelii* (Shaw & Nodder, 1797)	4
59	Testudines	Geoemydidae	*Cuora amboinensis* (Riche in Daudin, 1801)	2, 4, 7
60	Testudines	Geoemydidae	*Cuora mouhotii* (Gray, 1862)	4, 7
61	Testudines	Geoemydidae	*Cyclemys gemeli* (Fritz, Guicking, Auer, Sommer, Wink & Hundsdörfer, 2008)	4, 7
62	Testudines	Geoemydidae	*Geoclemys hamiltonii* (Gray, 1830)	P, 2, 4, 5, 7
63	Testudines	Geoemydidae	*Hardella thurjii* (Gray, 1831)	2, 4, 7

S.No.	Order	Family	Scientific name (IUCN)	Literature
64	Testudines	Geoemydidae	*Melanochelys tricarinata* (Blyth, 1856)	2, 4, 7
65	Testudines	Geoemydidae	*Morenia petersi* (Anderson, 1879)	4, 7
66	Testudines	Geoemydidae	*Pangshura smithii* (Gray, 1863)	2, 4, 7
67	Testudines	Geoemydidae	*Pangshura sylhetensis* (Jerdon, 1870)	4, 5, 7
68	Testudines	Geoemydidae	*Pangshura tecta* (Gray, 1830)	2, 4, 7
69	Testudines	Geoemydidae	*Pangshura tentoria* (Gray, 1834)	2, 4, 7
70	Testudines	Testudinidae	*Manouria emys* (Schlegel & Müller, 1840)	4, 7
71	Testudines	Trionychidae	*Chitra indica* (Gray, 1830)	4, 7
72	Testudines	Trionychidae	*Lissemys punctata* (Lacépède, 1788)	2, 4, 7
73	Testudines	Trionychidae	*Nilssonia gangetica* (Cuvier, 1825)	2, 4
74	Testudines	Trionychidae	*Nilssonia hurum* (Gray, 1830)	2, 4, 7
75	Testudines	Trionychidae	*Nilssonia nigricans* (Anderson, 1875)	4, 7

Population- Population trend from IUCN (2022), IUCN status- International Union for Conservation of Nature, DD- Data Deficient, NE- Not Evaluated, LC- Least Concern, NT- Near Threatened, VU- Vulnerable, EN- Endangered, CR- Critically Endangered, IWPA- Wild Life (Protection) Act, 1972, CITES- Convention on International Trade in Endangered Species of Wild Fauna and Flora, P- recorded during present study, 1- Pathak (1978), 2- Bhupathy et al. (1992), 3- Choudhury (2004), 4- Ahmed et al. (2005), 5- Baruah (2007), 6- Das et al. (2007), 7- Basumatary & Sharma (2013)

Appendix 5. Actinopterygii diversity in Kaziranga Tiger Reserve, Assam

S.No.	Order	Family	Scientific name (IUCN)	Literature
1	Beloniformes	Belonidae	*Xenentodon cancila* (Hamilton, 1822)	1, 4
2	Clupeiformes	Clupeidae	*Gudusia chapra* (Hamilton, 1822)	1, 4
3	Clupeiformes	Clupeidae	*Tenualosa ilisha* (Hamilton, 1822)	P
4	Cypriniformes	Nemacheilidae	*Paracanthocobitis botia* (Hamilton, 1822)	3
5	Cypriniformes	Balitoridae	*Balitora brucei* (Gray, 1830)	5
6	Cypriniformes	Nemacheilidae	*Schistura savona* (Hamilton, 1822)	5
7	Cypriniformes	Botiidae	*Botia dario* (Hamilton, 1822)	3, 5
8	Cypriniformes	Cobitidae	*Lepidocephalichthys goalparensis* Pillai & Yazdani, 1976	5
9	Cypriniformes	Cobitidae	*Lepidocephalichthys irrorata* Hora, 1921	3
10	Cypriniformes	Cobitidae	*Lepidocephalichthys menoni* Pillai & Yazdani, 1976	3
11	Cypriniformes	Danionidae	*Amblypharyngodon mola* (Hamilton, 1822)	P, 1, 4
12	Cypriniformes	Cyprinidae	*Gymnostomus ariza* (Hamilton, 1807)	5
13	Cypriniformes	Cyprinidae	*Opsarius barna* (Hamilton, 1822)	5
14	Cypriniformes	Cyprinidae	*Bengala elanga* (Hamilton, 1822)	P, 1, 4
15	Cypriniformes	Cyprinidae	*Chagunius chagunio* (Hamilton, 1822)	5
16	Cypriniformes	Cyprinidae	*Cirrhinus mrigala* (Hamilton 1822)	P, 1, 4
17	Cypriniformes	Cyprinidae	*Devario devario* (Hamilton, 1822)	5
18	Cypriniformes	Cyprinidae	*Esomus danrica* (Hamilton, 1822)	5
19	Cypriniformes	Cyprinidae	*Gibelion catla* (Hamilton, 1822)	P, 1, 4
20	Cypriniformes	Cyprinidae	*Labeo bata* (Hamilton, 1822)	P, 1, 4
21	Cypriniformes	Cyprinidae	*Labeo boga* (Hamilton, 1822)	5
22	Cypriniformes	Cyprinidae	*Labeo boggut* (Sykes, 1839)	5
23	Cypriniformes	Cyprinidae	*Labeo calbasu* (Hamilton, 1822)	P, 1, 4
24	Cypriniformes	Cyprinidae	*Labeo gonius* (Hamilton, 1822)	P, 1, 4
25	Cypriniformes	Cyprinidae	*Labeo nandina* (Hamilton, 1822)	P, 1, 4
26	Cypriniformes	Cyprinidae	*Labeo rohita* (Hamilton, 1822)	P, 1, 4
27	Cypriniformes	Cyprinidae	*Laubuca laubuca* (Hamilton, 1822)	6
28	Cypriniformes	Cyprinidae	*Oreichthys cosuatis* (Hamilton, 1822)	2
29	Cypriniformes	Cyprinidae	*Osteobrama cotio* (Hamilton, 1822)	5
30	Cypriniformes	Cyprinidae	*Pethia ticto* (Hamilton, 1822)	P, 1, 4
31	Cypriniformes	Cyprinidae	*Puntius sophore* (Hamilton, 1822)	P
32	Cypriniformes	Cyprinidae	*Rasbora daniconius* (Hamilton, 1822)	1, 4
33	Cypriniformes	Cyprinidae	*Salmophasia bacaila* (Hamilton, 1822)	1, 4, 5
34	Cypriniformes	Cyprinidae	*Securicula gora* (Hamilton, 1822)	5
35	Cypriniformes	Cyprinidae	*Systomus sarana* (Hamilton, 1822)	P, 1, 4
36	Cypriniformes	Cyprinidae	*Tariqilabeo latius* (Hamilton, 1822)	5
37	Cypriniformes	Nemacheilidae	*Acanthocobitis pavonacea* (McClelland, 1839)	5
38	Cypriniformes	Nemacheilidae	*Paracanthocobitis botia* (Hamilton, 1822)	5
39	Osteoglossiformes	Notopteridae	*Chitala chitala* (Hamilton, 1822)	P, 1, 4
40	Osteoglossiformes	Notopteridae	*Notopterus notopterus* (Pallas, 1769)	P, 1, 4
41	Perciformes	Ambassidae	*Chanda nama* (Hamilton, 1822)	P, 1, 4
42	Perciformes	Ambassidae	*Parambassis ranga* (Hamilton, 1822)	5
43	Perciformes	Anabantidae	*Anabas testudineus* (Bloch, 1792)	P, 4
44	Perciformes	Badidae	*Badis badis* (Hamilton, 1822)	5
45	Perciformes	Channidae	*Channa amphibeus* (McClelland, 1845)	1, 4

S.No.	Order	Family	Scientific name (IUCN)	Literature
46	Perciformes	Channidae	*Channa gachua* (Hamilton 1822)	5
47	Perciformes	Channidae	*Channa marulius* (Hamilton, 1822)	P, 1, 4
48	Perciformes	Channidae	*Channa orientalis* (Bloch & Schneider, 1801)	1, 4
49	Perciformes	Channidae	*Channa punctata* (Bloch, 1793)	P, 1, 4
50	Perciformes	Channidae	*Channa striata* (Bloch, 1793)	1, 4
51	Perciformes	Gobiidae	*Glossogobius giuris* (Hamilton, 1822)	1, 4
52	Perciformes	Nandidae	*Nandus nandus* (Hamilton, 1822)	P, 1, 4
53	Perciformes	Osphronemidae	*Trichogaster chuna* (Hamilton, 1822)	P, 1
54	Perciformes	Osphronemidae	*Trichogaster fasciata* (Bloch & Schneider, 1801)	1, 4
55	Perciformes	Osphronemidae	*Trichogaster lalius* (Hamilton, 1822)	4
56	Siluriformes	Amblycipitidae	*Amblyceps laticeps* (McClelland, 1842)	5
57	Siluriformes	Bagridae	*Chandramara chandramara* (Hamilton, 1822)	5
58	Siluriformes	Bagridae	*Hemibagrus menoda* (Hamilton, 1822)	1, 4
59	Siluriformes	Bagridae	*Mystus bleekeri* (Day, 1877)	1, 4
60	Siluriformes	Bagridae	*Mystus cavasius* (Hamilton, 1822)	P, 1, 4
61	Siluriformes	Bagridae	Mystus sp	5
62	Siluriformes	Bagridae	*Mystus vittatus* (Bloch, 1794)	1, 4
63	Siluriformes	Bagridae	*Sperata aor* (Hamilton, 1822)	5
64	Siluriformes	Bagridae	*Sperata seenghala* (Sykes, 1839)	P, 4
65	Siluriformes	Clariidae	*Clarias batrachus* (Linnaeus, 1758)	P, 1, 4
66	Siluriformes	Erethistidae	*Erethistes pusillus* (Müller & Troschel, 1849)	5
67	Siluriformes	Heteropneustidae	*Heteropneustes fossilis* (Bloch, 1794)	P, 1, 4
68	Siluriformes	Ailiidae	*Eutropiichthys vacha* (Hamilton, 1822)	P, 1, 4
69	Siluriformes	Schilbeidae	*Pachypterus atherinoides* (Bloch, 1794)	5
70	Siluriformes	Siluridae	*Ompok pabo* (Hamilton, 1822)	P, 1, 4
71	Siluriformes	Siluridae	*Wallago attu* (Bloch & Schneider, 1801)	P, 1, 4
72	Siluriformes	Sisoridae	*Bagarius bagarius* (Hamilton, 1822)	P, 1, 4
73	Siluriformes	Sisoridae	*Gagata cenia* (Hamilton, 1822)	5
74	Synbranchiformes	Chaudhuriidae	*Garo khajuriai* (Talwar, Yazdani & Kundu, 1977)	3
75	Synbranchiformes	Mastacembelidae	*Macrognathus aral* (Bloch & Schneider, 1801)	5
76	Synbranchiformes	Mastacembelidae	*Macrognathus pancalus* Hamilton, 1822	5
77	Synbranchiformes	Mastacembelidae	*Mastacembelus armatus* (Lacepède, 1800)	P, 1, 4
78	Synbranchiformes	Synbranchidae	*Monopterus cuchia* (Hamilton, 1822)	P, 1, 4
79	Syngnathiformes	Syngnathidae	*Microphis deocata* (Hamilton, 1822)	5
80	Tetraodontiformes	Tetraodontidae	*Leiodon cutcutia* (Hamilton, 1822)	P, 1, 4

Population- Population trend from IUCN (2022), IUCN status- International Union for Conservation of Nature, DD- Data Deficient, NE- Not Evaluated, LC- Least Concern, NT- Near Threatened, VU- Vulnerable, IWPA- Wild Life (Protection) Act, 1972, P- recorded during present study, 1- Pathak (1978), 2- Tilak & Sati (1984), 3- Menon (1999), 4- Vasu (2003), 5- Laskar et al., (2018), 6- Kullender et al. (2018)

Appendix 6. Amphibia diversity in Kaziranga Tiger Reserve, Assam

S.No.	Order	Family	Scientific name (IUCN)	Literature
1	Anura	Bufonidae	*Duttaphrynus melanostictus* (Schneider, 1799)	2
2	Anura	Dicroglossidae	*Euphlyctis cyanophlyctis* (Schneider, 1799)	2
3	Anura	Dicroglossidae	*Fejervarya limnocharis* (Gravenhorst, 1829	2
4	Anura	Dicroglossidae	*Minervarya syhadrensis* (Annandale, 1919)	2
5	Anura	Dicroglossidae	*Hoplobatrachus crassus* (Jerdon, 1854 "1853")	2
6	Anura	Dicroglossidae	*Hoplobatrachus tigerinus* (Daudin, 1802)	2
7	Anura	Dicroglossidae	*Limnonectes laticeps* (Boulenger, 1882)	1, 2
8	Anura	Dicroglossidae	*Limnonectes sp.*	2
9	Anura	Hylidae	*Hyla annectans* (Jerdon, 1870)	1, 2
10	Anura	Megophryidae	*Leptobrachium smithi* (Matsui, Nabhitabhata & Panha, 1999)	2
11	Anura	Megophryidae	*Megophrys parva* (Boulenger, 1893)	1, 2
12	Anura	Microhylidae	*Microhyla ornata* (Duméril & Bibron, 1841)	1, 2
13	Anura	Microhylidae	*Microhyla rubra* (Jerdon, 1854)	1, 2
14	Anura	Ranidae	*Humerana humeralis* (Boulenger, 1887)	2
15	Anura	Ranidae	*Hydrophylax leptoglossa* (Cope, 1868)	2
16	Anura	Ranidae	*Hylarana taipehensis* (van Denburgh, 1909)	2
17	Anura	Ranidae	*Hylarana tytleri* (Theobald, 1868)	2
18	Anura	Dicroglossidae	*Ingerana borealis* (Annandale, 1912)	2
19	Anura	Rhacophoridae	*Chirixalus simus (*Annandale, 1915)	2
20	Anura	Rhacophoridae	*Rohanixalus vittatus* (Boulenger, 1887)	2
21	Anura	Rhacophoridae	*Polypedates leucomystax* (Gravenhorst, 1829)	1, 2
22	Anura	Rhacophoridae	*Rhacophorus bipunctatus* (Ahl, 1927)	1, 2
23	Anura	Rhacophoridae	*Rhacophorus maximus* (Günther, 1858)	2

S.No.	Order	Family	Scientific name (IUCN)	Literature
24	Anura	Rhacophoridae	*Theloderma asperum* (Boulenger, 1886)	2

Population- Population trend from IUCN (2022), IUCN status- International Union for Conservation of Nature, NE- Not Evaluated, LC- Least Concern, VU- Vulnerable, IWPA- Wild Life (Protection) Act, 1972, CITES- Convention on International Trade in Endangered Species of Wild Fauna and Flora, P- recorded during present study, 1- Chanda (1994), 2- Ahmed et al. (2005)

Appendix 7. Insecta diversity in Kaziranga Tiger Reserve, Assam

S.No.	Order	Family	Scientific name (IUCN)	Literature
1	Lepidoptera	Hesperiidae	*Aeromachus jhora creta* (Evans, 1949)	3
2	Lepidoptera	Hesperiidae	*Aeromachus kali* (De Nicéville, 1885)	3
3	Lepidoptera	Hesperiidae	*Aeromachus pygmaeus* (Fabricius, 1775)	3
4	Lepidoptera	Hesperiidae	*Aeromachus stigmata obsoleta* (Moore, 1878)	3
5	Lepidoptera	Hesperiidae	*Ampittia dioscorides* (Fabricius, 1793)	3
6	Lepidoptera	Hesperiidae	*Ampittia maroides* (De Nicéville, 1896)	3
7	Lepidoptera	Hesperiidae	*Ancistroides nigrita diocles* (Moore, 1865)	3
8	Lepidoptera	Hesperiidae	*Apostictopterus fuliginosus* (Leech, 1894)	3
9	Lepidoptera	Hesperiidae	*Astictopterus jama olivascens* (Moore, 1878)	3
10	Lepidoptera	Hesperiidae	*Badamia exclamationis* (Fabricius, 1775)	3
11	Lepidoptera	Hesperiidae	*Baoris farri* (Moore, 1878)	3
12	Lepidoptera	Hesperiidae	*Baoris penicillata chapmani* (Evans, 1937)	3
13	Lepidoptera	Hesperiidae	*Bibasis amara* (Moore, 1865)	3
14	Lepidoptera	Hesperiidae	*Bibasis gomata* (Moore, 1865)	3
15	Lepidoptera	Hesperiidae	*Bibasis harisa* (Moore, 1865)	3
16	Lepidoptera	Hesperiidae	*Bibasis mahintha* (Moore, 1875)	3
17	Lepidoptera	Hesperiidae	*Bibasis oedipodea* (Swainson, 1820)	3
18	Lepidoptera	Hesperiidae	*Bibasis sena uniformis* (Elwes & Edwards, 1897)	3
19	Lepidoptera	Hesperiidae	*Caltoris aurociliata* (Elwes & Edwards, 1897)	3
20	Lepidoptera	Hesperiidae	*Caltoris bromus* (Leech, 1844)	3
21	Lepidoptera	Hesperiidae	*Caltoris cara* (Evans, 1932)	3
22	Lepidoptera	Hesperiidae	*Caltoris kumara* (Moore, 1878)	3
23	Lepidoptera	Hesperiidae	*Caltoris moolata* (Moore, 1878)	3
24	Lepidoptera	Hesperiidae	*Caltoris pagana* (De Niceville, 1887)	3
25	Lepidoptera	Hesperiidae	*Caltoris philippina* (Herrich-Schäffer, 1869)	3
26	Lepidoptera	Hesperiidae	*Caltoris plebeia* (De Nicéville, 1887)	3
27	Lepidoptera	Hesperiidae	*Caltoris sirius* (Evans, 1926)	3
28	Lepidoptera	Hesperiidae	*Celaenorrhinus aurivittata* (Moore, 1878)	3
29	Lepidoptera	Hesperiidae	*Celaenorrhinus morena* (Evans, 1949)	3
30	Lepidoptera	Hesperiidae	*Celaenorrhinus zea* (Swinhoe, 1909)	3
31	Lepidoptera	Hesperiidae	*Cephrenes acalle* (Höpffer, 1874)	3
32	Lepidoptera	Hesperiidae	*Chamunda chamunda* (Moore, 1865)	3
33	Lepidoptera	Hesperiidae	*Choaspes benjaminii japonica* (Murray, 1875)	3
34	Lepidoptera	Hesperiidae	*Choaspes hemixanthus furcata* (Evans, 1932)	3
35	Lepidoptera	Hesperiidae	*Choaspes plateni caudata* (Evans, 1932)	3
36	Lepidoptera	Hesperiidae	*Choaspes plateni stigmata* (Evans, 1932)	3
37	Lepidoptera	Hesperiidae	*Coladenia agni* (de Nicéville, 1883)	3
38	Lepidoptera	Hesperiidae	*Coladenia agnioides* (Elwes & Edwards, 1897)	3
39	Lepidoptera	Hesperiidae	*Coladenia laxmi laxmi* (de Nicéville, 1889)	3
40	Lepidoptera	Hesperiidae	*Cupitha purreea* (Moore, 1877)	3
41	Lepidoptera	Hesperiidae	*Erionota thrax thrax* (Linnaeus, 1767)	3
42	Lepidoptera	Hesperiidae	*Gangara thyrsis thyrsis* (Fabricius, 1775)	3
43	Lepidoptera	Hesperiidae	*Gerosis phisara* (Moore, 1884)	3
44	Lepidoptera	Hesperiidae	*Halpe arcuata* (Evans, 1937)	3
45	Lepidoptera	Hesperiidae	*Halpe flava* (Evans, 1926)	3
46	Lepidoptera	Hesperiidae	*Halpe hauxwelli* (Evans, 1937)	3
47	Lepidoptera	Hesperiidae	*Halpe homolea aucma* (Swinhoe, 1923)	3
48	Lepidoptera	Hesperiidae	*Halpe insignis* (Distant, 1886)	3
49	Lepidoptera	Hesperiidae	*Halpe knyvetti* (Elwes & Edwards, 1897)	3
50	Lepidoptera	Hesperiidae	*Halpe kusala* (Fruhstorfer, 1911)	3
51	Lepidoptera	Hesperiidae	*Halpe porus* (Mabille, 1876)	3
52	Lepidoptera	Hesperiidae	*Halpe sikkima* (Moore, 1882)	3
53	Lepidoptera	Hesperiidae	*Halpe wantona* (Swinhoe, 1893)	3
54	Lepidoptera	Hesperiidae	*Halpe zema* (Hewitson, 1877)	3
55	Lepidoptera	Hesperiidae	*Halpe zola* (Evans, 1937)	3
56	Lepidoptera	Hesperiidae	*Hasora badra* (Moore, 1857)	3
57	Lepidoptera	Hesperiidae	*Hasora chromus* (Cramer, 1780)	3
58	Lepidoptera	Hesperiidae	*Hasora khoda coulteri* (Wood-Mason & de Nicéville, 1886)	3

S.No.	Order	Family	Scientific name (IUCN)	Literature
59	Lepidoptera	Hesperiidae	*Hasora taminatus bhavara* (Fruhstorfer, 1911)	3
60	Lepidoptera	Hesperiidae	*Hasora vitta vitta* (Butler, 1870)	3
61	Lepidoptera	Hesperiidae	*Hyarotis adrastus praba* (Moore, 1865)	3
62	Lepidoptera	Hesperiidae	*Iambrix salsala* (Moore, 1865)	3
63	Lepidoptera	Hesperiidae	*Iton semamora semamora* (Moore, 1865)	3
64	Lepidoptera	Hesperiidae	*Koruthaialos butleri butleri* (de Nicéville, 1883)	3
65	Lepidoptera	Hesperiidae	*Koruthaialos rubecula cachara* (Evans, 1949)	3
66	Lepidoptera	Hesperiidae	*Koruthaialos xanites gopaka* (Fruhstorfer, 1910)	3
67	Lepidoptera	Hesperiidae	*Lotongus calathus zalates* (Mabille, 1893)	3
68	Lepidoptera	Hesperiidae	*Lotongus sarala sarala* (de Nicéville, 1889)	3
69	Lepidoptera	Hesperiidae	*Matapa aria* (Moore, 1865)	3
70	Lepidoptera	Hesperiidae	*Matapa cresta* (Evans, 1949)	3
71	Lepidoptera	Hesperiidae	*Matapa druna* (Moore, 1865)	3
72	Lepidoptera	Hesperiidae	*Matapa purpurascens* (Elwes & Edwards, 1897)	3
73	Lepidoptera	Hesperiidae	*Matapa sasivarna* (Moore, 1865)	3
74	Lepidoptera	Hesperiidae	*Mooreana trichoneura pralaya* (Moore, 1865)	3
75	Lepidoptera	Hesperiidae	*Notocrypta curvifascia* (Felder & Felder, 1862)	3
76	Lepidoptera	Hesperiidae	*Notocrypta paralysos volux* (Mabille, 1883)	3
77	Lepidoptera	Hesperiidae	*Notocrypta quadrata* (Elwes & Edwards, 1897)	3
78	Lepidoptera	Hesperiidae	*Ochus subvittatus subradiatus* (Moore, 1878)	3
79	Lepidoptera	Hesperiidae	*Odontoptilum angulata* (Felder, 1862)	3
80	Lepidoptera	Hesperiidae	*Oriens gola* (Moore, 1877)	3
81	Lepidoptera	Hesperiidae	*Parnara bada* (Moore, 1878)	3
82	Lepidoptera	Hesperiidae	*Parnara guttatus* (Bremer & Grey, 1853)	3
83	Lepidoptera	Hesperiidae	*Pelopidas assamensis* (De Nicéville, 1882)	3
84	Lepidoptera	Hesperiidae	*Pelopidas conjuncta* (Herrich-Schäffer, 1869)	3
85	Lepidoptera	Hesperiidae	*Pelopidas mathias* (Fabricius, 1798)	3
86	Lepidoptera	Hesperiidae	*Pelopidas sinensis* (Mabille, 1877)	3
87	Lepidoptera	Hesperiidae	*Pithauria marsena* (Hewitson, 1866)	3
88	Lepidoptera	Hesperiidae	*Pithauria murdava* (Moore, 1865)	3
89	Lepidoptera	Hesperiidae	*Pithauria stramineipennis* (Wood-Mason & de Nicéville, 1886)	3
90	Lepidoptera	Hesperiidae	*Polytremis lubricans* (Herrich-Schäffer, 1869)	3
91	Lepidoptera	Hesperiidae	*Potanthus confucius dushta* (Fruhstorfer, 1911)	3
92	Lepidoptera	Hesperiidae	*Potanthus flava alcon* (Evans, 1932)	3
93	Lepidoptera	Hesperiidae	*Potanthus ganda ganda* (Fruhstrofer, 1911)	3
94	Lepidoptera	Hesperiidae	*Potanthus juno* (Evans, 1932)	3
95	Lepidoptera	Hesperiidae	*Potanthus lydia lydia* (Evans, 1934)	3
96	Lepidoptera	Hesperiidae	*Potanthus mingo ajax* (Evans, 1932)	3
97	Lepidoptera	Hesperiidae	*Potanthus nesta* (Evans, 1934)	3
98	Lepidoptera	Hesperiidae	*Potanthus pallida* (Evans, 1932)	3
99	Lepidoptera	Hesperiidae	*Potanthus palnia palnia* (Evans, 1914)	3
100	Lepidoptera	Hesperiidae	*Potanthus pseudomaesa clio* (Evans, 1932)	3
101	Lepidoptera	Hesperiidae	*Potanthus rectifasciata rectifasciata* (Elwes & Edwards, 1897)	3
102	Lepidoptera	Hesperiidae	*Potanthus sita* (Evans, 1932)	3
103	Lepidoptera	Hesperiidae	*Potanthus trachala tytleri* (Evans, 1914)	3
104	Lepidoptera	Hesperiidae	*Pseudoborbo bevani* (Moore, 1878)	3
105	Lepidoptera	Hesperiidae	*Pseudocoldaenia dan faith* (Kollar β. dhyana Fruhstorfer, 1909)	3
106	Lepidoptera	Hesperiidae	*Psolos fuligo subfasciatus* (Moore, 1878)	3
107	Lepidoptera	Hesperiidae	*Pyroneura margherita* (Doherty, 1889)	3
108	Lepidoptera	Hesperiidae	*Pyroneura niasana* (Fruhstorfer, 1909)	3
109	Lepidoptera	Hesperiidae	*Salanoemia fuscicornis* (Elwes & Edwards, 1897)	3
110	Lepidoptera	Hesperiidae	*Sarangesa dasahara* (Moore, 1865)	3
111	Lepidoptera	Hesperiidae	*Scobura cephala* (Hewitson, 1876)	3
112	Lepidoptera	Hesperiidae	*Scobura cephaloides* (De Nicéville, 1888)	3
113	Lepidoptera	Hesperiidae	*Scobura isota* (Swinhoe, 1893)	3
114	Lepidoptera	Hesperiidae	*Scobura phiditia* (Hewitson, 1866)	3
115	Lepidoptera	Hesperiidae	*Seseria dohertyi* (Watson, 1893)	3
116	Lepidoptera	Hesperiidae	*Seseria sambara* (Moore, 1865)	3
117	Lepidoptera	Hesperiidae	*Spialia galba* (Fabricius, 1793)	3
118	Lepidoptera	Hesperiidae	*Stimula swinhoei* (Elwes & Edwards, 1897)	3
119	Lepidoptera	Hesperiidae	*Suastus gremius gremius* (Fabricius, 1798)	3
120	Lepidoptera	Hesperiidae	*Suastus minuta aditia* (Evans, 1949)	3
121	Lepidoptera	Hesperiidae	*Tagiades gana* (Moore, 1865)	3
122	Lepidoptera	Hesperiidae	*Tagiades japetus obscurus* (Mabille, 1876)	3
123	Lepidoptera	Hesperiidae	*Tagiades japetus ravi* (Moore, 1865)	3
124	Lepidoptera	Hesperiidae	*Tagiades litigiosa* (Möschler, 1878)	3
125	Lepidoptera	Hesperiidae	*Tagiades menaka* (Moore, 1865)	3

S.No.	Order	Family	Scientific name (IUCN)	Literature
126	Lepidoptera	Hesperiidae	*Telicota ancilla horisha* (Evans, 1934)	3
127	Lepidoptera	Hesperiidae	*Telicota bambusae* (Moore, 1878)	3
128	Lepidoptera	Hesperiidae	*Telicota besta* (Evans, 1949)	3
129	Lepidoptera	Hesperiidae	*Telicota colon* (Fabricius, 1775)	3
130	Lepidoptera	Hesperiidae	*Telicota linna* (Evans, 1949)	3
131	Lepidoptera	Hesperiidae	*Telicota ohara jix* (Evans, 1949)	3
132	Lepidoptera	Hesperiidae	*Thoressa cerata* (Hewitson, 1876)	3
133	Lepidoptera	Hesperiidae	*Thoressa fusca fusca* (Elwes, 1892)	3
134	Lepidoptera	Hesperiidae	*Udaspes folus* (Cramer, 1775)	3
135	Lepidoptera	Hesperiidae	*Zographetus ogygia ogygia* (Hewitson, 1866)	3
136	Lepidoptera	Hesperiidae	*Zographetus rama rama* (Mabille, 1876)	3
137	Lepidoptera	Hesperiidae	*Zographetus satwa* (de Nicéville, 1884)	3
138	Lepidoptera	Lycaenidae	*Abisara bifasciata suffusa* (Moore, 1882)	4
139	Lepidoptera	Lycaenidae	*Acytolepis puspa* (Horsfield, 1828)	4
140	Lepidoptera	Lycaenidae	*Allotinus drumila* (Moore, 1865)	4
141	Lepidoptera	Lycaenidae	*Ancema blanka* (de Nicéville, 1894)	4
142	Lepidoptera	Lycaenidae	*Ancema carmentalis* (De Nicéville, 1892)	4
143	Lepidoptera	Lycaenidae	*Anthene emolus* (Godart, 1824)	4
144	Lepidoptera	Lycaenidae	*Anthene lycaenina* (Felder, 1868)	4
145	Lepidoptera	Lycaenidae	*Aphnaeus elima* (Moore, 1877)	4
146	Lepidoptera	Lycaenidae	*Aphnaeus syama* (Horsfield, 1829)	4
147	Lepidoptera	Lycaenidae	*Araotes lapithis* (Moore, 1857)	4
148	Lepidoptera	Lycaenidae	*Arhopala abseus indicus* (Riley, 1923)	4
149	Lepidoptera	Lycaenidae	*Arhopala alax* (Evans, 1932)	4
150	Lepidoptera	Lycaenidae	*Arhopala ammonides* (Doherty, 1891)	4
151	Lepidoptera	Lycaenidae	*Arhopala athada apha* (de Nicéville, 1895)	4
152	Lepidoptera	Lycaenidae	*Arhopala atrax* (Hewitson, 1862)	4
153	Lepidoptera	Lycaenidae	*Arhopala bazaloides* (Hewitson, 1878)	4
154	Lepidoptera	Lycaenidae	*Arhopala bazalus teesta* (De Nicéville, 1886)	4
155	Lepidoptera	Lycaenidae	*Arhopala centaurus pirithous* (Moore, 1883)	4
156	Lepidoptera	Lycaenidae	*Arhopala eumolphus* (Stoll, 1780)	4
157	Lepidoptera	Lycaenidae	*Arhopala fulla ignara* (Riley & Godfrey, 1921)	4
158	Lepidoptera	Lycaenidae	*Arhopala hellenore* (Doherty, 1889)	4
159	Lepidoptera	Lycaenidae	*Arhopala horsfieldi eurysthenes* (Fruhstorfer, 1914)	4
160	Lepidoptera	Lycaenidae	*Arhopala nicevillei* (Bethune-Baker, 1903)	4
161	Lepidoptera	Lycaenidae	*Arhopala paramuta* (De Nicéville, 1884)	4
162	Lepidoptera	Lycaenidae	*Arhopala perimuta* (Moore, 1857)	4
163	Lepidoptera	Lycaenidae	*Arhopala silhetensis* (Hewitson, 1862)	4
164	Lepidoptera	Lycaenidae	*Arhopala zambra zambra* (Swinhoe 1910?)	4
165	Lepidoptera	Lycaenidae	*Artipe eryx* (Linnaeus, 1771)	4
166	Lepidoptera	Lycaenidae	*Artipe skinneri* (De Nicéville, 1887)	4
167	Lepidoptera	Lycaenidae	*Bindahara phocides* (Fabricius, 1793)	4
168	Lepidoptera	Lycaenidae	*Castalius rosimon* (Fabricius, 1775)	4
169	Lepidoptera	Lycaenidae	*Catachrysops lithargyria* (Doherty, 1891)	4
170	Lepidoptera	Lycaenidae	*Catapoecilma elegans* (H. Druce, 1873)	4
171	Lepidoptera	Lycaenidae	*Catochrysops strabo* (Fabricius, 1793)	4
172	Lepidoptera	Lycaenidae	*Celastrina argiolus sikkima* (Moore, 1883)	4
173	Lepidoptera	Lycaenidae	*Celastrina lavendularis limbata* (Moore, 1879)	4
174	Lepidoptera	Lycaenidae	*Charana mandarinus* (Hewitson, 1863)	4
175	Lepidoptera	Lycaenidae	*Cheritra freja* (Fabricius, 1793)	4
176	Lepidoptera	Lycaenidae	*Chilades laius* (Cramer, 1782)	4
177	Lepidoptera	Lycaenidae	*Chliaria othona* (Hewitson, 1865)	4
178	Lepidoptera	Lycaenidae	*Creon cleobis* (Godart, 1824)	4
179	Lepidoptera	Lycaenidae	*Curetis bulis* (Westwood, 1851)	4
180	Lepidoptera	Lycaenidae	*Curetis dentata dentata* (Moore, 1879)	4
181	Lepidoptera	Lycaenidae	*Curetis saronis gloriosa* (Moore, 1883)	4
182	Lepidoptera	Lycaenidae	*Dacalana cotys* (Hewitson, 1865)	4
183	Lepidoptera	Lycaenidae	*Dacalana vidura pencilligera* (De Nicéville, 1890)	4
184	Lepidoptera	Lycaenidae	*Deudorix epijarbas* (Moore, 1858)	4
185	Lepidoptera	Lycaenidae	*Discolampa ethion* (Westwood, 1851)	4
186	Lepidoptera	Lycaenidae	*Euchrysops cnejus* (Fabricius, 1798)	4
187	Lepidoptera	Lycaenidae	*Everes lacturnus assamica* (Tytler, 1915)	4
188	Lepidoptera	Lycaenidae	*Flos apidanus ahamus* (Doherty, 1891)	4
189	Lepidoptera	Lycaenidae	*Flos diardi diardi* (Hewitson, 1862)	4
190	Lepidoptera	Lycaenidae	*Heliophorus epicles* (Godart, 1824)	4
191	Lepidoptera	Lycaenidae	*Horaga onyx onyx* (Moore, 1857)	4
192	Lepidoptera	Lycaenidae	*Hypolycaena erylus* (Godart, 1823)	4

S.No.	Order	Family	Scientific name (IUCN)	Literature
193	Lepidoptera	Lycaenidae	*Ionolyce helicon merguiana* (Moore, 1884)	4
194	Lepidoptera	Lycaenidae	*Iraota timoleon* (Stoll, 1790)	4
195	Lepidoptera	Lycaenidae	*Jamides alecto* (C. Felder, 1860)	4
196	Lepidoptera	Lycaenidae	*Jamides caerulea* (Druce, 1873)	4
197	Lepidoptera	Lycaenidae	*Jamides celeno* (Cramer, 1775)	4
198	Lepidoptera	Lycaenidae	*Jamides elpis* (Godart, 1824)	4
199	Lepidoptera	Lycaenidae	*Jamides cleodus pura* (Moore, 1886)	4
200	Lepidoptera	Lycaenidae	*Lampides bochus* (Cramer, 1782)	4
201	Lepidoptera	Lycaenidae	*Lampides boeticus* (Linnaeus, 1767)	4
202	Lepidoptera	Lycaenidae	*Leptotes plinius* (Fabricius, 1793)	4
203	Lepidoptera	Lycaenidae	*Loxura atymnus* (Cramer, 1780)	4
204	Lepidoptera	Lycaenidae	*Lycaenopsis transpectus* (Moore, 1879)	4
205	Lepidoptera	Lycaenidae	*Megisba malaya* (Horsfield, 1828)	4
206	Lepidoptera	Lycaenidae	*Miletus boisduvali (*Moore, 1858)	4
207	Lepidoptera	Lycaenidae	*Miletus chinensis assamensis* (Doherty, 1891)	4
208	Lepidoptera	Lycaenidae	*Miletus nymphis* (Fruhstorfer, 1913)	4
209	Lepidoptera	Lycaenidae	*Nacaduba beroe gythion* (Fruhstorfer, 1916)	4
210	Lepidoptera	Lycaenidae	*Nacaduba hermus* (Felder, 1860)	4
211	Lepidoptera	Lycaenidae	*Nacaduba kurava* (Moore, 1857)	4
212	Lepidoptera	Lycaenidae	*Nacaduba pactolus continentalis* (Fruhstorfer, 1916)	4
213	Lepidoptera	Lycaenidae	*Nacaduba pavana pavana* (Horsfield, 1828)	4
214	Lepidoptera	Lycaenidae	*Nacaduba pavana vajuva* (Fruhstorfer, 1916)	4
215	Lepidoptera	Lycaenidae	*Neopithecops zalmora* (Butler, 1870)	4
216	Lepidoptera	Lycaenidae	*Petrelaea dana* (de Nicéville, 1884)	4
217	Lepidoptera	Lycaenidae	*Pithecops corvus* (Fruhstorfer, 1919)	4
218	Lepidoptera	Lycaenidae	*Pithecops hylax* (Horsfield, 1828)	4
219	Lepidoptera	Lycaenidae	*Poritia erycinoides elsiei* (Evans, 1925)	4
220	Lepidoptera	Lycaenidae	*Poritia hewitsoni* (Moore, 1865)	4
221	Lepidoptera	Lycaenidae	*Prosotas dubiosa indica* (Evans, 1925)	4
222	Lepidoptera	Lycaenidae	*Prosotas lutea* (Martin, 1895)	4
223	Lepidoptera	Lycaenidae	*Prosotas nora ardates* (Moore, 1875)	4
224	Lepidoptera	Lycaenidae	*Pseudozizeeria maha* (Kollar, 1844)	4
225	Lepidoptera	Lycaenidae	*Pycnophallium elna* (Hewitson, 1876)	4
226	Lepidoptera	Lycaenidae	*Rachana jalindra indra* (Moore, 1883)	4
227	Lepidoptera	Lycaenidae	*Rapala damona* (Swinhoe, 1890)	4
228	Lepidoptera	Lycaenidae	*Rapala dieneces* (Hewitson, 1878)	4
229	Lepidoptera	Lycaenidae	*Rapala manea schistacea* (Moore, 1879)	4
230	Lepidoptera	Lycaenidae	*Rapala pheretima petosiris* (Hewitson, 1863)	4
231	Lepidoptera	Lycaenidae	*Rapala rhoecus* (de Nicéville, 1895)	4
232	Lepidoptera	Lycaenidae	*Rapala scintilla* (De Nicéville, 1890)	4
233	Lepidoptera	Lycaenidae	*Rapala suffusa* (Moore, 1878)	4
234	Lepidoptera	Lycaenidae	*Rapala varuna orseis* (Hewitson, 1863)	4
235	Lepidoptera	Lycaenidae	*Sinthusa chandrana grotei* (Moore, 1883)	4
236	Lepidoptera	Lycaenidae	*Sinthusa nasaka amba* (Kirby, 1878)	4
237	Lepidoptera	Lycaenidae	*Spalgis epius* (Westwood, 1851)	4
238	Lepidoptera	Lycaenidae	*Spindasis elwesi* (Evans, 1925)	4
239	Lepidoptera	Lycaenidae	*Spindasis lohita himalayanus* (Moore, 1884)	4
240	Lepidoptera	Lycaenidae	*Surendra quercetorum* (Moore, 1857)	4
241	Lepidoptera	Lycaenidae	*Tarucus callinara* (Butler, 1886)	4
242	Lepidoptera	Lycaenidae	*Tarucus theophrastus indica* (Evans, 1932)	4
243	Lepidoptera	Lycaenidae	*Ticherra acte* (Moore, 1858)	4
244	Lepidoptera	Lycaenidae	*Udara dilecta* (Moore, 1879)	4
245	Lepidoptera	Lycaenidae	*Virachola isocrates* (Fabricius, 1793)	4
246	Lepidoptera	Lycaenidae	*Virachola perse perse* (Hewitson, 1863)	4
247	Lepidoptera	Lycaenidae	*Yasoda tripunctata* (Hewitson, 1863)	4
248	Lepidoptera	Lycaenidae	*Zeltus etolus* (Fabricius, 1787)	4
249	Lepidoptera	Lycaenidae	*Zemeros flegyas* (Cramer, 1780)	4
250	Lepidoptera	Lycaenidae	*Zizeeria karsandra* (Moore, 1865)	4
251	Lepidoptera	Lycaenidae	*Zizeeria otis* (Fabricius, 1787)	4
252	Lepidoptera	Riodinidae	*Abisara echeria* (Stoll, 1790)	4
253	Lepidoptera	Riodinidae	*Abisara neophron* (Hewitson, 1860)	4
254	Odonata	Aeshnidae	*Anaciaeschna jaspidea* (Burmeister, 1839)	5
255	Odonata	Aeshnidae	*Anax guttatus* (Burmeister, 1839)	5
256	Odonata	Aeshnidae	*Gynacantha bainbriggei* (Fraser, 1922)	5
257	Odonata	Aeshnidae	*Gynacantha bayadera* (Selys, 1891)	5
258	Odonata	Aeshnidae	*Gynacantha dravida* (Lieftinck,1960)	5
259	Odonata	Calopterygidae	*Matrona nigripectus* (Selys, 1879)	5

S.No.	Order	Family	Scientific name (IUCN)	Literature
260	Odonata	Calopterygidae	*Neurobasis chinensis* (Linnaeus, 1758)	5
261	Odonata	Calopterygidae	*Vestalis gracilis* (Rambur, 1842)	5
262	Odonata	Chlorocyphidae	*Libellago lineata* (Burmeister, 1839)	5
263	Odonata	Chlorocyphidae	*Heliocypha biforata* (Sélys, 1859)	5
264	Odonata	Chlorocyphidae	*Aristocypha fenestrella* (Rambur, 1842)	5
265	Odonata	Chlorocyphidae	*Aristocypha quadrimaculata* (Selys, 1853)	5
266	Odonata	Chlorocyphidae	*Rhinocypha vitrinella* (Fraser, 1935)	5
267	Odonata	Coenagrionidae	*Aciagrion occidentale* (Laidlaw, 1919)	5
268	Odonata	Coenagrionidae	*Aciagrion pallidum* (Selys, 1891)	5
269	Odonata	Coenagrionidae	*Agriocnemis clauseni* (Fraser, 1922)	5
270	Odonata	Coenagrionidae	*Agriocnemis femina* (Brauer, 1868)	5
271	Odonata	Coenagrionidae	*Agriocnemis kalinga* (Nair & Subra., 2014)	5
272	Odonata	Coenagrionidae	*Agriocnemis lacteola* (Sélys, 1877)	5
273	Odonata	Coenagrionidae	*Agriocnemis pygmaea* (Rambur, 1842)	5
274	Odonata	Coenagrionidae	*Argiocnemis rubescens* (Selys, 1877)	5
275	Odonata	Coenagrionidae	*Ceriagrion cerinorubellum* (Brauer, 1865)	5
276	Odonata	Coenagrionidae	*Ceriagrion coromandelianum* (Fabricius, 1798)	5
277	Odonata	Coenagrionidae	*Ceriagrion fallax* (Ris, 1914)	5
278	Odonata	Coenagrionidae	*Ceriagrion olivaceum* (Laidlaw, 1914)	5
279	Odonata	Coenagrionidae	*Amphiallagma parvum* (Selys, 1876)	5
280	Odonata	Coenagrionidae	*Ischnura aurora* (Brauer, 1865)	5
281	Odonata	Coenagrionidae	*Ischnura senegalensis* (Rambur, 1842)	5
282	Odonata	Coenagrionidae	*Mortonagrion aborense* (Laidlaw, 1914)	5
283	Odonata	Platycnemididae	*Onychargia atrocyana* (Sélys, 1865)	5
284	Odonata	Coenagrionidae	*Pseudagrion decorum* (Rambur, 1842)	5
285	Odonata	Coenagrionidae	*Pseudagrion microcephalum* (Rambur, 1842)	5
286	Odonata	Coenagrionidae	*Pseudagrion rubriceps* (Selys, 1876)	5
287	Odonata	Euphaeidae	*Euphaea ochracea* (Selys, 1859)	5
288	Odonata	Gomphidae	*Ictinogomphus rapax* (Rambur, 1842)	5
289	Odonata	Gomphidae	*Paragomphus lineatus* (Selys, 1850)	5
290	Odonata	Lestidae	*Lestes praemorsus* (Hagen in Selys, 1892)	5
291	Odonata	Lestidae	*Lestes viridulus* (Rambur, 1842)	5
292	Odonata	Libellulidae	*Acisoma panorpoides* (Rambur, 1842)	5
293	Odonata	Libellulidae	*Aethriamanta brevipennis* (Rambur, 1842)	5
294	Odonata	Libellulidae	*Brachydiplax chalybea* (Brauer, 1868)	5
295	Odonata	Libellulidae	*Brachydiplax sobrina* (Rambur, 1842)	5
296	Odonata	Libellulidae	*Brachythemis contaminata* (Fabricius, 1793)	5
297	Odonata	Libellulidae	*Bradinopyga geminata* (Rambur, 1842)	5
298	Odonata	Libellulidae	*Camacinia gigantea* (Brauer, 1867)	5
299	Odonata	Libellulidae	*Crocothemis servilia* (Drury, 1773)	5
300	Odonata	Libellulidae	*Diplacodes nebulosa* (Fabricius, 1793)	5
301	Odonata	Libellulidae	*Diplacodes trivialis* (Rambur, 1842)	5
302	Odonata	Libellulidae	*Hydrobasileus croceus* (Brauer, 1867)	5
303	Odonata	Libellulidae	*Lathrecista asiatica* (Fabricius, 1798)	5
304	Odonata	Libellulidae	*Lyriothemis* sp	5
305	Odonata	Libellulidae	*Neurothemis fulvia* (Drury, 1773)	5
306	Odonata	Libellulidae	*Neurothemis intermedia* (Rambur, 1842)	5
307	Odonata	Libellulidae	*Neurothemis tullia* (Drury, 1773)	5
308	Odonata	Libellulidae	*Orthetrum chrysis* (Selys, 1891)	5
309	Odonata	Libellulidae	*Orthetrum glaucum* (Brauer, 1865)	5
310	Odonata	Libellulidae	*Orthetrum pruinosum* (Burmeister, 1839)	5
311	Odonata	Libellulidae	*Orthetrum sabina* (Drury, 1773)	5
312	Odonata	Libellulidae	*Orthetrum triangulare* (Selys, 1878)	5
313	Odonata	Libellulidae	*Palpopleura sexmaculata* (Fabricius, 1787)	5
314	Odonata	Libellulidae	*Pantala flavescens* (Fabricius, 1798)	5
315	Odonata	Libellulidae	*Potamarcha congener* (Rambur, 1842)	5
316	Odonata	Libellulidae	*Rhodothemis rufa* (Rambur, 1842)	5
317	Odonata	Libellulidae	*Rhyothemis plutonia* (Selys, 1883)	5
318	Odonata	Libellulidae	*Rhyothemis triangularis* (Kirby, 1889)	5
319	Odonata	Libellulidae	*Rhyothemis variegata* (Linnaeus, 1763)	5
320	Odonata	Libellulidae	*Tholymis tillarga* (Fabricius, 1798)	5
321	Odonata	Libellulidae	*Tramea basilaris* (Palisot de Beauvois, 1807)	5
322	Odonata	Libellulidae	*Tramea limbata* (Desjardins, 1835)	5
323	Odonata	Libellulidae	*Trithemis aurora* (Burmeister, 1839)	5
324	Odonata	Libellulidae	*Trithemis festiva* (Rambur, 1842)	5
325	Odonata	Libellulidae	*Trithemis pallidinervis* (Kirby, 188)	5
326	Odonata	Libellulidae	*Urothemis signata* (Rambur, 1842)	5

S.No.	Order	Family	Scientific name (IUCN)	Literature
327	Odonata	Libellulidae	*Zyxomma petiolatum* (Rambur, 1842)	5
328	Odonata	Platycnemididae	*Calicnemia eximia* (Selys, 1863)	5
329	Odonata	Platycnemididae	*Calicnemia imitans* (Lieftinck, 1948)	5
330	Odonata	Platycnemididae	*Coeliccia schmidti* (Asahina, 1984)	5
331	Odonata	Platycnemididae	*Copera marginipes* (Rambur, 1842)	5
332	Odonata	Platycnemididae	*Copera vittata* (Selys, 1863)	5
333	Odonata	Platycnemididae	*Elattoneura campioni* (Fraser, 1922)	5
334	Odonata	Platystictidae	*Drepanosticta* sp	5
335	Odonata	Platystictidae	*Protosticta* sp	5
336	Orthoptera	Acrididae	*Acrida exaltata* (Walker, F., 1859)	1
337	Orthoptera	Acrididae	*Atractomorpha crenulata* (Fabricius, 1793)	1
338	Orthoptera	Acrididae	*Atractomorpha* sp.	1
339	Orthoptera	Acrididae	*Caryanda* sp.	1
340	Orthoptera	Acrididae	*Catantops ferruginuous* (Walk.)	1
341	Orthoptera	Acrididae	*Eyprepocnemis alacris* (Serville, 1838)	1
342	Orthoptera	Acrididae	*Gesonula punctifrons* (Stål, 1861)	1
343	Orthoptera	Acrididae	*Heiroglyphus banian* (Fab.)	1
344	Orthoptera	Acrididae	*Oxya hyla* (Serville, 1831)	1
345	Orthoptera	Acrididae	*Oxya nitidula* (Walker, F., 1870)	1
346	Orthoptera	Acrididae	*Phlaeoba antennata* (Brunner von Wattenwyl, 1893)	1
347	Orthoptera	Acrididae	*Phlaeoba infumata* (Brunner von Wattenwyl, 1893)	1
348	Orthoptera	Acrididae	*Phlaeoba* sp.	1
349	Orthoptera	Acrididae	*Phlaeoba tenebrosa* (Walker, F., 1871)	1
350	Orthoptera	Acrididae	*Spathosternum prasiniferum* (Walker, F., 1871)	1
351	Orthoptera	Acrididae	*Trilophidia annulata* (Thunberg, 1815)	1
352	Orthoptera	Acrididae	*Xenocatantops humilis* (Serville, 1838)	1
353	Orthoptera	Gryllidae	*Gryllinae* sp.	1
354	Orthoptera	Gryllidae	*Gryllodes sigillatus* (Walker, F., 1869)	1
355	Orthoptera	Gryllidae	*Teleogryllus* sp.	1
356	Orthoptera	Mantidae	*Creobroter* sp.	1
357	Orthoptera	Mantidae	*Hierodula* sp.	1
358	Orthoptera	Mantidae	*Mantodea* sp.	1
359	Orthoptera	Mantidae	*Statilia* sp.	1
360	Orthoptera	Mantidae	*Tenodera* sp.	1
361	Orthoptera	Pyrgomorphidae	*Orthacris maindroni* (Bolívar, I., 1905)	1
362	Orthoptera	Pyrgomorphidae	*Tagasta indica* (Bolívar, I., 1905)	1
363	Orthoptera	Tettigoniidae	*Conocephalus maculatus* (Le Guillou, 1841)	1
364	Orthoptera	Tettigoniidae	*Conocephalus melaenus* (Haan, 1843)	1
365	Orthoptera	Tettigoniidae	*Hexacentrus major* (Redtenbacher, 1891)	1
366	Orthoptera	Tettigoniidae	*Hexacentrus unicolor* (Serville, 1831)	1
367	Orthoptera	Tettigoniidae	*Khaoyaiana* sp.	1
368	Orthoptera	Tettigoniidae	*Letana rubescens* (Stål, 1861)	1
369	Orthoptera	Tettigoniidae	*Mirrollia* sp.	1
370	Orthoptera	Tettigoniidae	*Orthelimaea securigera* (Brunner von Wattenwyl, 1878)	1
371	Orthoptera	Tettigoniidae	*Ruspolia indica* (Redtenbacher, 1891)	1
372	Thysanoptera	Phlaeothripidae	*Androthrips flavitibia* (Moulton, 1932)	2
373	Thysanoptera	Phlaeothripidae	*Androthrips ramachandrai* (Karny, 1926)	2
374	Thysanoptera	Phlaeothripidae	*Araeothrips longisetis* (Ananthakrishnan, 1976)	2
375	Thysanoptera	Phlaeothripidae	*Araeothrips vamana* (Muraleedharan, 1982)	2
376	Thysanoptera	Phlaeothripidae	*Arrhenothrips longisetis* (Sen, 1977)	2
377	Thysanoptera	Phlaeothripidae	*Bamboosiella nayari* (Ananthakrishnan, 1958)	2
378	Thysanoptera	Phlaeothripidae	*Crotonothrips cacharensis* (Muraleedharan & Sen,1978)	2
379	Thysanoptera	Phlaeothripidae	*Dexiothrips madrasensis* (Ananthakrishnan, 1964)	2
380	Thysanoptera	Phlaeothripidae	*Dinothrips sumatrensis* (Bagnall, 1908)	2
381	Thysanoptera	Phlaeothripidae	*Dolichothrips indicus* (Hood, 1919)	2
382	Thysanoptera	Phlaeothripidae	*Dolichothrips montanus* (Ananthakrishnan, 1964)	2
383	Thysanoptera	Phlaeothripidae	*Ecacanthothrips tibialis* (Ashmead, 1905)	2
384	Thysanoptera	Phlaeothripidae	*Elaphrothrips curvipes* (Priesner, 1929)	2
385	Thysanoptera	Phlaeothripidae	*Elaphrothrips denticollis* (Bagnall, 1914)	2
386	Thysanoptera	Phlaeothripidae	*Elaphrothrips greeni* (Bagnall, 1914)	2
387	Thysanoptera	Phlaeothripidae	*Elaphrothrips procer* (Schmutz, 1913)	2
388	Thysanoptera	Phlaeothripidae	*Elaphrothrips spiniceps* (Bagnall, 1932)	2
389	Thysanoptera	Phlaeothripidae	*Eurynchothrips ordinarius* (Hood, 1919)	2
390	Thysanoptera	Phlaeothripidae	*Gigantothrips elegans* (Zimmerman, 1900)	2
391	Thysanoptera	Phlaeothripidae	*Gigantothrips tibialis* (Bagnall, 1921)	2
392	Thysanoptera	Phlaeothripidae	*Gynaikothrips bengalensis* (Ananthakrishnan, 1973)	2
393	Thysanoptera	Phlaeothripidae	*Gynaikothrips cecidii* (Ananthakrishnan, 1968)	2

S.No.	Order	Family	Scientific name (IUCN)	Literature
394	Thysanoptera	Phlaeothripidae	*Gynaikothrips uzeli* (Zimmermann, 1900)	2
395	Thysanoptera	Phlaeothripidae	*Haplothrips (Haplothrips) montanus* (Ananthakrishnan & Jagadish, 1970)	2
396	Thysanoptera	Phlaeothripidae	*Haplothrips ceylonicus* (Schmutz, 1913)	2
397	Thysanoptera	Phlaeothripidae	*Haplothrips ganglbaueri* (Schmutz, 1913)	2
398	Thysanoptera	Phlaeothripidae	*Haplothrips gowdeyi* (Franklin, 1908)	2
399	Thysanoptera	Phlaeothripidae	*Haplothrips longisetosus* (Ananthakrishnan, 1955)	2
400	Thysanoptera	Phlaeothripidae	*Haplothrips tenuipennis* (Bagnall, 1918)	2
401	Thysanoptera	Phlaeothripidae	*Hoplandrothrips flavipes* (Bagnall, 1923)	2
402	Thysanoptera	Phlaeothripidae	*Hoplothrips fungosus* (Moulton, 1928)	2
403	Thysanoptera	Phlaeothripidae	*Leeuwenia ananthakrishnani* (Varatharajan and Sen, 2000)	2
404	Thysanoptera	Phlaeothripidae	*Leeuwenia karnyiana* (Priesner, 1925)	2
405	Thysanoptera	Phlaeothripidae	*Liophloeothrips amoenus* (Ananthakrishnan, 1966)	2
406	Thysanoptera	Phlaeothripidae	*Liophloeothrips pavettae (*Ananthakrishnan and Jagadish, 1969)	2
407	Thysanoptera	Phlaeothripidae	*Liothrips aequilus* (Ananthakrishnan and Jagadish, 1969)	2
408	Thysanoptera	Phlaeothripidae	*Liothrips associatus* (Ananthakrishnan and Jagadish, 1969)	2
409	Thysanoptera	Phlaeothripidae	*Liothrips himalayanus* (Ananthakrishnan & Jagadish, 1970)	2
410	Thysanoptera	Phlaeothripidae	*Liothrips infrequens* (Muraleedharan and Sen, 1979)	2
411	Thysanoptera	Phlaeothripidae	*Liothrips mohanrami* (Bhatti et al., 2006)	2
412	Thysanoptera	Phlaeothripidae	*Liothrips morulus* (Ananthakrishnan and Jagadish, 1970)	2
413	Thysanoptera	Phlaeothripidae	*Liothrips ramakrishnae* (Ananthakrishnan and Jagadish, 1969)	2
414	Thysanoptera	Phlaeothripidae	*Meiothrips nepalensis* (Kudo and Ananthakrishnan, 1974)	2
415	Thysanoptera	Phlaeothripidae	*Membrothrips indicus* (Hood, 1919)	2
416	Thysanoptera	Phlaeothripidae	*Mesothrips ambasensis* (Muraleedharan and Sen, 1981)	2
417	Thysanoptera	Phlaeothripidae	*Mesothrips extensivus* (Ananthakrishnan & Jagadish, 1969)	2
418	Thysanoptera	Phlaeothripidae	*Mesothrips lividicornis* (Karny, 1923)	2
419	Thysanoptera	Phlaeothripidae	*Mimothrips orientalis* (Ananthakrishnan, 1949)	2
420	Thysanoptera	Phlaeothripidae	*Neodixothrips assamensis* (Sen and Muraleedharan, 1976)	2
421	Thysanoptera	Phlaeothripidae	*Nesothrips brevicollis* (Bagnall, 1914)	2
422	Thysanoptera	Phlaeothripidae	*Nesothrips lativentris* (Karny, 1913)	2
423	Thysanoptera	Phlaeothripidae	*Tylothrips indicus* (Sen & Muraleedharan, 1977)	2
424	Thysanoptera	Phlaeothripidae	*Xylaplothrips pusillus* (Ananthakrishnan & Jagadish,1969)	2
425	Thysanoptera	Thripidae	*Anaphothrips sudanensis (*Trybom, 1911)	2
426	Thysanoptera	Thripidae	*Astrothrips tumiceps* (Karny, 1923)	2
427	Thysanoptera	Thripidae	*Ayyaria chaetophora* (Karny 1927)	2
428	Thysanoptera	Thripidae	*Chaetanaphothrips orchidii* (Moulton, 1907)	2
429	Thysanoptera	Thripidae	*Craspedothrips minor* (Bagnall, 1921)	2
430	Thysanoptera	Thripidae	*Dendrothrips stannardi* (Ananthakrishnan, 1957)	2
431	Thysanoptera	Thripidae	*Dichromothrips nakahari* (Mound, 1976)	2
432	Thysanoptera	Thripidae	*Dichromothrips smithi* (Zimmerman, 1900)	2
433	Thysanoptera	Thripidae	*Frankliniella intonsa* (Trybom, 1895)	2
434	Thysanoptera	Thripidae	*Fulmekiola serrata* (Kubos, 1893)	2
435	Thysanoptera	Thripidae	*Helionothrips kadaliphilus* (Ramakrishna and Margabandhu, 1931)	2
436	Thysanoptera	Thripidae	*Helionothrips parvus* (Bhatti, 1968)	2
437	Thysanoptera	Thripidae	*Hydatothrips aureus* (Bhatti, 1973)	2
438	Thysanoptera	Thripidae	*Lefroyothrips lefroyi* (Bagnall, 1913)	2
439	Thysanoptera	Thripidae	*Megalurothrips distalis* (Karny 1913)	2
440	Thysanoptera	Thripidae	*Megalurothrips mucunae* (Priesner, 1938)	2
441	Thysanoptera	Thripidae	*Megalurothrips pecularis* (Bagnall, 1918)	2
442	Thysanoptera	Thripidae	*Megalurothrips typicus* (Bagnall, 1915)	2
443	Thysanoptera	Thripidae	*Megalurothrips usitatus* (Bagnall, 1913)	2
444	Thysanoptera	Thripidae	*Microcephalothrips abdominalis* (D. L. Crawford, 1910)	2
445	Thysanoptera	Thripidae	*Monilothrips kempi* (Moulton, 1929)	2
446	Thysanoptera	Thripidae	*Mycterothrips setiventris* (Bagnall, 1918)	2
447	Thysanoptera	Thripidae	*Neohydatothrips raniae* (Bhatti, 1967)	2
448	Thysanoptera	Thripidae	*Panchaetothrips indicus* (Bagnall, 1912)	2
449	Thysanoptera	Thripidae	*Phibalothrips peringueyi* (Faure, 1925)	2
450	Thysanoptera	Thripidae	*Retithrips syriacus* (Mayet, 1890)	2
451	Thysanoptera	Thripidae	*Rhamphothrips parviceps* (Hood, 1919)	2
452	Thysanoptera	Thripidae	*Rhipiphorothrips cruentatus* (Hood, 1919)	2
453	Thysanoptera	Thripidae	*Sciothrips cardamomi* (Ramakrishna, 1935)	2
454	Thysanoptera	Thripidae	*Scirtothrips dorsalis* (Hood, 1919)	2
455	Thysanoptera	Thripidae	*Selenothrips rubrocinctus* (Giard, 1901)	2
456	Thysanoptera	Thripidae	*Stenchaetothrips biformis* (Bagnall, 1913)	2
457	Thysanoptera	Thripidae	*Taeniothrips major* (Bagnall, 1916)	2
458	Thysanoptera	Thripidae	*Thrips andrewsi* (Bagnall, 1921)	2
459	Thysanoptera	Thripidae	*Thrips coloratus* (Schmutz, 1913)	2
460	Thysanoptera	Thripidae	*Thrips flavidulus* (Bagnall, 1923)	2

S.No.	Order	Family	Scientific name (IUCN)	Literature
461	Thysanoptera	Thripidae	*Thrips flavus* (Schrank, 1776)	2
462	Thysanoptera	Thripidae	*Thrips hawaiiensis* (Morgan, 1913)	2
463	Thysanoptera	Thripidae	*Thrips kodaikanalensis* (Ananthakrishnan and Jagadish, 1966)	2
464	Thysanoptera	Thripidae	*Thrips orientalis* (Bagnall, 1915)	2
465	Thysanoptera	Thripidae	*Thrips palmi (*Karny, 1925)	2
466	Thysanoptera	Thripidae	*Thrips tabaci* (Lindeman, 1889)	2
467	Thysanoptera	Thripidae	*Zaniothrips ricini* (Bhatti, 1967)	2

Population- Population trend from IUCN (2022), IUCN status- International Union for Conservation of Nature, NE- Not Evaluated, DD- Data Deficient, LC- Least Concern, IWPA- Wild Life (Protection) Act, 1972, CITES- Convention on International Trade in Endangered Species of Wild Fauna and Flora, P- recorded during present study, 1- Senthilkumar (2010), 2- Singh & Varatharajan (2013), 3- Gogoi (2013), 4- Gogoi (2015), 5- Boruah et al., (2016)

Appendix 8. Review of the threats to the ungulates in the Kaziranga Tiger Reserve, Assam.

Threat	Description	Reason	Taxa affected	Literature
Habitat fragmentation	NH 37 highway; Increased settlement nearby NH 37; Agriculture expansion; Tea garden	Increased anthropogenic pressure and developmental activities	Rhino, Asian Elephant, Asiatic Wild buffalo, Swamp deer, Hog deer, Wild boar and Barking deer	b, f, g
Poaching	Horn	Traditional medicine purpose	Rhino, Asiatic Wild buffalo and Swamp deer	d
Flood	High flood during 1988, 1998, 2004 and 2012	Making animals more prone to drowning	Rhino, Asian Elephant, Asiatic Wild buffalo, Swamp deer, Hog deer and Wild boar	b, f
Accident	Road Kill	During high flood level wild animal migrate to karbi areas which makes them more prone to poaching, accident and drowning	Rhino, Hog deer, Barking deer, Wild boar, Reptiles	e
Disease	Transmission of disease like rinderpest and anthrax	Due to cattle grazing	Asian Elephant, Asiatic Wild buffalo, Swamp deer and Hog deer	a, b
Dog kill	Street dogs attacks the animal	Meat	Hog deer	Present study
Burning	Late burning may affect the fawn and calves	Sometimes burning till April	Rhino, Swamp deer and herpetofauna (python, turtle and frog)	b, c
Overgrazing	Grazing by domestic cattle on the fringes of the park	Cows, goats and buffaloes grazing might decrease the forage availability for other wild animals and also increase the chances of spread of disease	Rhino, Asian Elephant, Asiatic Wild buffalo, Swamp deer, Hog deer and Sambar	Present study

[a]Choudhury (1994), [b]Bonal (1998), [c]Ahmed et al. (2005), [d]Patar (2005), [e]Das et al. (2007), [f]Yadava (2014) and [g]Sharma & Sarma (2014)

Appendix 9. Number of faecal samples collected for mega and meso-herbivores during 2013-15 in Kaziranga National Park, Assam.

Species	Season	Sample collected	Composite samples	Slides Prepared	Slides Observation
Greater One-horned Rhino	Overall	350	70	350	3500
	Dry	250	50	250	2500
	Wet	100	20	100	1000
Asian Elephant	Overall	350	70	350	3500
	Dry	250	50	250	2500
	Wet	100	20	100	1000
Asiatic Wild Buffalo	Overall	325	65	325	3250
	Dry	250	50	250	2500
	Wet	75	15	75	750
Swamp Deer	Overall	325	65	325	3250
	Dry	250	50	250	2500
	Wet	75	15	75	750
Hog Deer	Overall	325	65	325	3250
	Dry	250	50	250	2500
	Wet	75	15	75	750
Sambar	Overall	300	60	300	3000

Species	Season	Sample collected	Composite samples	Slides Prepared	Slides Observation
	Dry	250	50	250	2500
	Wet	50	10	50	500
Six Large Herbivores	**Overall**	**1975**	**395**	**1975**	**19750**
	Dry	**1500**	**300**	**1500**	**15000**
	Wet	**475**	**95**	**475**	**4750**

Appendix 10. Diet composition (percentage of occurrence) of Greater One-horned Rhino (*Rhinoceros unicornis*) during 2013-15 in Kaziranga National Park, Assam.

Greater One-horned Rhino					
			Percentage of occurrence (%)		
				Season	
Plant species	**Monocot / Dicot**	**Growth form**	**Overall (n=7)**	**Dry (n=5)**	**Wet (n=2)**
Ziziphus jujuba Mill.	Dicot	Tree	4.40	3.91	5.53
Mallotus nudiflorus (L.) Kulju & Welzen	Dicot	Tree	2.69	3.14	1.66
Lippia alba (Mill.) N.E.Br. ex Britton & P.Wilson	Dicot	Shrub	2.60	3.04	1.62
Amaranthus spinosus L.	Dicot	Herb	2.49	2.68	2.05
Ageratum conyzoides (L.) L.	Dicot	Herb	2.09	2.27	1.70
Persicaria hydropiper (L.) Delarbre	Dicot	Herb	1.70	2.06	0.89
Dillenia indica L.	Dicot	Tree	1.61	1.81	1.16
Solanum americanum Mill.	Dicot	Herb	1.48	1.35	1.78
Crotalaria albida Roth	Dicot	Shrub	1.31	1.23	1.51
Acmella uliginosa (Sw.) Cass.	Dicot	Herb	1.28	1.67	0.39
Duchesnea indica (Andrews) Focke	Dicot	Herb	1.17	1.11	1.31
Leucas aspera (Willd.) Link	Dicot	Herb	1.14	1.40	0.54
Mikania micrantha Kunth	Dicot	Climber	1.05	1.28	0.54
Nelsonia canescens (Lam.) Spreng.	Dicot	Herb	0.91	0.97	0.77
Laphangium luteoalbum (L.) Tzvelev	Dicot	Herb	0.91	1.11	0.46
Merremia sp.	Dicot	Climber	0.89	0.92	0.81
Chenopodium album L.	Dicot	Herb	0.84	0.77	1.01
Solanum viarum Dunal	Dicot	Shrub	0.83	0.82	0.85
Flemingia lineata (L.) Aiton	Dicot	Shrub	0.82	0.84	0.77
Melilotus albus Medik.	Dicot	Herb	0.82	0.90	0.62
Acacia sp.	Dicot	Tree	0.82	0.84	0.77
Grangea maderaspatana (L.) Poir.	Dicot	Herb	0.79	0.84	0.70
Pouzolzia zeylanica (L.) Benn. & R. Br.	Dicot	Herb	0.79	0.78	0.81
Heliotropium indicum L.	Dicot	Herb	0.59	0.68	0.39
Oenanthe javanica (Blume) DC.	Dicot	Herb	0.57	0.56	0.58
Oxalis corniculata L.	Dicot	Herb	0.53	0.56	0.46
Tetrastigma dubium (Lawson) Planch.	Dicot	Climber	0.53	0.20	1.28
Ranunculus sceleratus L.	Dicot	Herb	0.49	0.48	0.50
Rungia pectinata (L.) Nees	Dicot	Herb	0.49	0.56	0.31
Amaranthus viridis L.	Dicot	Herb	0.40	0.17	0.93
Polygonum plebeium R.Br.	Dicot	Herb	0.38	0.26	0.66
Cannabis sativa L.	Dicot	Herb	0.36	0.36	0.35
Hypericum sp.	Dicot	Shrub	0.33	0.09	0.89
Litsea salicifolia (Roxburgh ex Nees) Hook. f.	Dicot	Shrub	0.32	0.38	0.19
Artemisia sp.	Dicot	Herb	0.28	0.02	0.89
Dalbergia sissoo DC.	Dicot	Tree	0.27	0.19	0.46
Cotula hemispherica (Roxb.) Raizada	Dicot	Herb	0.19	0.24	0.08
Stachytarpheta indica (L.) Vahl	Dicot	Shrub	0.18	0.17	0.19
Cajanus scarabaeoides (L.) Thouars	Dicot	Climber	0.17	0.17	0.15
Mimosa spp.	Dicot	Shrub	0.14	0.09	0.27
Urena lobata L.	Dicot	Shrub	0.13	0.07	0.27
Cleome spinosa Jacq.	Dicot	Herb	0.12	0.00	0.39
Rorippa indica (L.) Hiern	Dicot	Herb	0.11	0.09	0.15
Glochidion multiloculare (Rottler ex Willd.) Voigt	Dicot	Shrub	0.09	0.14	0.00
Ludwigia adscendens (L.) H.Hara	Dicot	Herb	0.07	0.05	0.12
Xanthium strumarium L.	Dicot	Herb	0.04	0.03	0.04
Rumex dentatus L.	Dicot	Herb	0.04	0.00	0.12
Flueggea virosa (Roxb. ex Willd.) Royl	Dicot	Shrub	0.02	0.03	0.00
Youngia japonica (L.) DC.	Dicot	Herb	0.01	0.00	0.04

Greater One-horned Rhino					
Plant species	Monocot / Dicot	Growth form	Percentage of occurrence (%)		
			Overall (n=7)	Season	
				Dry (n=5)	Wet (n=2)
Saccharum spp.	Monocot	Grass	12.59	12.03	13.88
Echinochloa crus-galli (L.) P.Beauv.	Monocot	Grass	5.49	5.61	5.22
Cynodon dactylon (L.) Pers.	Monocot	Grass	4.94	4.95	4.91
Hemarthria compressa (L.f.) R.Br.	Monocot	Grass	4.37	4.15	4.87
Alpinia nigra (Gaertn.) Burtt	Monocot	Herb	3.52	3.75	2.98
Carex vesicaria L.	Monocot	Sedge	3.33	2.85	4.41
Kyllinga brevifolia Rottb.	Monocot	Sedge	2.84	3.14	2.16
Fimbristylis aestivalis Vahl	Monocot	Sedge	2.54	2.47	2.71
Imperata cylindrica (L.) Raeusch.	Monocot	Grass	1.93	1.79	2.24
Chrysopogon aciculatus (Retz.) Trin.	Monocot	Grass	1.61	1.96	0.81
Setaria pumila (Poir.) Roem. & Schult.	Monocot	Grass	1.15	0.96	1.58
Paspalum conjugatum P.J.Bergius	Monocot	Grass	0.97	0.73	1.51
Panicum sp.	Monocot	Grass	0.89	1.16	0.27
Eleusine indica (L.) Gaertn.	Monocot	Grass	0.89	0.82	1.04
Cyrtococcum sp.	Monocot	Grass	0.70	0.70	0.70
Eleocharis acutangula (Roxb.) Schult.	Monocot	Sedge	0.54	0.56	0.50
Fimbristylis dichotoma (L.) Vahl	Monocot	Sedge	0.17	0.20	0.08
*Oplismenus*sp.	Monocot	Grass	0.13	0.07	0.27
Calamus tenuis Roxb.	Monocot	Shrub	0.09	0.00	0.31
Setaria sp.	Monocot	Grass	0.04	0.00	0.12
Identified Monocot (%)			**48.72**	**47.90**	**50.56**
Unidentified Monocot (%)			**8.42**	**8.10**	**9.12**
Total Monocot (%)			**57.13**	**56.00**	**59.68**
Identified Dicot (%)			**40.28**	**41.30**	**37.96**
Unidentified Dicot (%)			**2.59**	**2.70**	**2.36**
Total Dicot (%)			**42.87**	**44.00**	**40.32**
Total (%)			**100.00**	**100.00**	**100.00**

n- number of months

Appendix 11. Diet composition (percentage of occurrence) of Asian elephant (*Elephas maximus*) during 2013-15 in Kaziranga National Park, Assam.

Asian Elephant					
Plant species	Monocot/ Dicot	Growth form	Percentage of occurrence (%)		
			Overall (n=7)	Season	
				Dry (n=5)	Wet (n=2)
Ziziphus jujuba Mill.	Dicot	Tree	6.18	6.16	6.24
Mallotus nudiflorus (L.) Kulju & Welzen	Dicot	Tree	4.11	3.51	5.59
Dillenia indica L.	Dicot	Tree	3.35	3.62	2.71
Lippia alba (Mill.) N.E.Br. ex Britton & P.Wilson	Dicot	Shrub	2.49	2.70	1.98
Ageratum conyzoides (L.) L.	Dicot	Herb	1.40	1.72	0.60
Acmella uliginosa (Sw.) Cass.	Dicot	Herb	1.31	1.40	1.08
Litsea salicifolia (Roxburgh ex Nees) Hook. f.	Dicot	Shrub	1.27	1.40	0.95
Persicaria hydropiper (L.) Delarbre	Dicot	Herb	1.21	1.46	0.60
Acacia sp.	Dicot	Tree	1.02	0.81	1.55
Polygonum plebeium R.Br.	Dicot	Herb	1.02	1.25	0.47
Grangea maderaspatana (L.) Poir.	Dicot	Herb	0.93	1.11	0.52
Flemingia lineata (L.) Aiton	Dicot	Shrub	0.92	1.11	0.47
Chenopodium album L.	Dicot	Herb	0.90	0.98	0.69
Nelsonia canescens (Lam.) Spreng.	Dicot	Herb	0.89	1.02	0.56
Urena lobata L.	Dicot	Shrub	0.87	0.77	1.12
Ranunculus sceleratus L.	Dicot	Herb	0.81	0.75	0.95
Dalbergia sissoo DC.	Dicot	Tree	0.80	0.98	0.34
Duchesnea indica (Andrews) Focke	Dicot	Herb	0.79	0.82	0.69
Mikania micrantha Kunth	Dicot	Climber	0.76	0.93	0.34
Laphangium luteoalbum (L.) Tzvelev	Dicot	Herb	0.71	0.81	0.47
Cannabis sativa L.	Dicot	Herb	0.71	0.88	0.30
Ludwigia adscendens (L.) H.Hara	Dicot	Herb	0.66	0.65	0.69
Solanum americanum Mill.	Dicot	Herb	0.65	0.67	0.60
Amaranthus viridis L.	Dicot	Herb	0.59	0.58	0.60
Leucas aspera (Willd.) Link	Dicot	Herb	0.56	0.58	0.52

Asian Elephant					
Plant species	Monocot/ Dicot	Growth form	Percentage of occurrence (%)		
			Overall (n=7)	Season	
				Dry (n=5)	Wet (n=2)
Amaranthus spinosus L.	Dicot	Herb	0.54	0.51	0.60
Solanum viarum Dunal	Dicot	Shrub	0.54	0.54	0.52
Pouzolzia zeylanica (L.) Benn. & R. Br.	Dicot	Herb	0.50	0.42	0.69
Cajanus scarabaeoides (L.) Thouars	Dicot	Climber	0.49	0.51	0.43
Tetrastigma dubium (Lawson) Planch.	Dicot	Climber	0.47	0.56	0.26
Oxalis corniculata L.	Dicot	Herb	0.46	0.49	0.39
Melilotus albus Medik.	Dicot	Herb	0.45	0.46	0.43
Glochidion multiloculare (Rottler ex Willd.) Voigt	Dicot	Shrub	0.45	0.49	0.34
Merremia sp.	Dicot	Climber	0.41	0.47	0.26
Crotalaria albida Roth	Dicot	Shrub	0.41	0.49	0.22
Hypericum sp.	Dicot	Shrub	0.37	0.44	0.22
Rorippa indica (L.) Hiern	Dicot	Herb	0.35	0.47	0.04
Cotula hemispherica (Roxb.) Raizada	Dicot	Herb	0.24	0.33	0.00
Rungia pectinata (L.) Nees	Dicot	Herb	0.22	0.21	0.26
Heliotropium indicum L.	Dicot	Herb	0.20	0.26	0.04
Oenanthe javanica (Blume) DC.	Dicot	Herb	0.16	0.19	0.09
Stachytarpheta indica (L.) Vahl	Dicot	Shrub	0.11	0.12	0.09
Xanthium strumarium L.	Dicot	Herb	0.05	0.05	0.04
Mimosa spp.	Dicot	Shrub	0.04	0.05	0.00
Youngia japonica (L.) DC.	Dicot	Herb	0.02	0.04	0.00
Artemisia sp.	Dicot	Herb	0.01	0.02	0.00
Saccharum spp.	Monocot	Grass	13.99	11.69	19.61
Calamus tenuis Roxb.	Monocot	Shrub	7.07	8.29	4.09
Carex vesicaria L.	Monocot	Sedge	3.80	3.05	5.63
Echinochloa crus-galli (L.) P.Beauv.	Monocot	Grass	3.58	3.48	3.83
Hemarthria compressa (L.f.) R.Br.	Monocot	Grass	3.22	2.35	5.33
Alpinia nigra (Gaertn.) Burtt	Monocot	Herb	2.75	3.25	1.55
Cynodon dactylon (L.) Pers.	Monocot	Grass	2.33	2.09	2.92
Fimbristylis aestivalis Vahl	Monocot	Sedge	2.12	2.11	2.15
Setaria pumila (Poir.) Roem. & Schult.	Monocot	Grass	1.86	1.93	1.68
Imperata cylindrica (L.) Raeusch.	Monocot	Grass	1.73	1.32	2.75
Kyllinga brevifolia Rottb.	Monocot	Sedge	1.58	1.54	1.68
Eleocharis acutangula (Roxb.) Schult.	Monocot	Sedge	0.85	1.02	0.43
*Oplismenus*sp.	Monocot	Grass	0.75	0.95	0.26
Paspalum conjugatum P.J.Bergius	Monocot	Grass	0.70	0.81	0.43
Eleusine indica (L.) Gaertn.	Monocot	Grass	0.65	0.63	0.69
Chrysopogon aciculatus (Retz.) Trin.	Monocot	Grass	0.42	0.49	0.26
Fimbristylis dichotoma (L.) Vahl	Monocot	Sedge	0.39	0.44	0.26
Cyrtococcum sp.	Monocot	Grass	0.15	0.18	0.09
Setaria sp.	Monocot	Grass	0.11	0.16	0.00
Cyperus squarrosus L.	Monocot	Sedge	0.05	0.07	0.00
Panicum sp.	Monocot	Grass	0.05	0.04	0.09
Identified Monocot (%)			**48.14**	**45.87**	**53.72**
Unidentified Monocot (%)			**5.40**	**4.86**	**6.71**
Total Monocot (%)			**53.54**	**50.73**	**60.43**
Identified Dicot (%)			**41.41**	**43.81**	**35.53**
Unidentified Dicot (%)			**5.05**	**5.46**	**4.04**
Total Dicot (%)			**46.46**	**49.27**	**39.57**
Total (%)			**100.00**	**100.00**	**100.00**

n- number of months

Appendix 12. Diet composition (percentage of occurrence) of Asiatic wild buffalo (*Bubalus arnee*) during 2013-15 in Kaziranga National Park, Assam.

Asiatic Wild Buffalo					
Plant species	Monocot/ Dicot	Growth form	Percentage of occurrence (%)		
			Overall (n=7)	Season	
				Dry (n=5)	Wet (n=2)
Ziziphus jujuba Mill.	Dicot	Tree	4.80	5.00	4.10
Oxalis corniculata L.	Dicot	Herb	2.44	2.51	2.20
Lippia alba (Mill.) N.E.Br. ex Britton & P.Wilson	Dicot	Shrub	1.91	2.14	1.10

Asiatic Wild Buffalo					
Plant species	Monocot/ Dicot	Growth form	Percentage of occurrence (%)		
			Overall (n=7)	Season	
				Dry (n=5)	Wet (n=2)
Solanum americanum Mill.	Dicot	Herb	1.82	1.80	1.89
Mallotus nudiflorus (L.) Kulju & Welzen	Dicot	Tree	1.81	1.87	1.59
Persicaria hydropiper (L.) Delarbre	Dicot	Herb	1.77	1.78	1.71
Acmella uliginosa (Sw.) Cass.	Dicot	Herb	1.62	1.61	1.65
Amaranthus viridis L.	Dicot	Herb	1.40	1.43	1.28
Leucas aspera (Willd.) Link	Dicot	Herb	1.34	1.04	2.38
Solanum viarum Dunal	Dicot	Shrub	1.08	1.17	0.79
Duchesnea indica (Andrews) Focke	Dicot	Herb	1.03	0.99	1.16
Mikania micrantha Kunth	Dicot	Climber	1.03	1.08	0.86
Polygonum plebeium R.Br.	Dicot	Herb	0.96	0.92	1.10
Dillenia indica L.	Dicot	Tree	0.95	1.01	0.73
Flemingia lineata (L.) Aiton	Dicot	Shrub	0.90	1.06	0.37
Nelsonia canescens (Lam.) Spreng.	Dicot	Herb	0.88	1.02	0.37
Crotalaria albida Roth	Dicot	Shrub	0.88	0.78	1.22
Chenopodium album L.	Dicot	Herb	0.86	0.74	1.28
Acacia sp.	Dicot	Tree	0.85	0.97	0.43
Melilotus albus Medik.	Dicot	Herb	0.78	0.81	0.67
Ageratum conyzoides (L.) L.	Dicot	Herb	0.58	0.49	0.86
Amaranthus spinosus L.	Dicot	Herb	0.56	0.49	0.79
Tetrastigma dubium (Lawson) Planch.	Dicot	Climber	0.56	0.46	0.92
Pouzolzia zeylanica (L.) Benn. & R. Br.	Dicot	Herb	0.53	0.58	0.37
Litsea salicifolia (Roxburgh ex Nees) Hook. f.	Dicot	Shrub	0.51	0.51	0.49
Merremia sp.	Dicot	Climber	0.49	0.57	0.24
Grangea maderaspatana (L.) Poir.	Dicot	Herb	0.45	0.55	0.12
Oenanthe javanica (Blume) DC.	Dicot	Herb	0.37	0.37	0.37
Ranunculus sceleratus L.	Dicot	Herb	0.34	0.44	0.00
Laphangium luteoalbum (L.) Tzvelev	Dicot	Herb	0.29	0.35	0.06
Dalbergia sissoo DC.	Dicot	Tree	0.23	0.28	0.06
Rungia pectinata (L.) Nees	Dicot	Herb	0.16	0.19	0.06
Cannabis sativa L.	Dicot	Herb	0.16	0.19	0.06
Cotula hemispherica (Roxb.) Raizada	Dicot	Herb	0.14	0.18	0.00
Urena lobata L.	Dicot	Shrub	0.12	0.05	0.37
Ludwigia adscendens (L.) H.Hara	Dicot	Herb	0.07	0.09	0.00
Stachytarpheta indica (L.) Vahl	Dicot	Shrub	0.07	0.04	0.18
Rorippa indica (L.) Hiern	Dicot	Herb	0.04	0.02	0.12
Youngia japonica (L.) DC.	Dicot	Herb	0.04	0.04	0.06
Hypericum sp.	Dicot	Shrub	0.04	0.05	0.00
Mimosa spp.	Dicot	Shrub	0.04	0.04	0.06
Heliotropium indicum L.	Dicot	Herb	0.03	0.02	0.06
Artemisia sp.	Dicot	Herb	0.01	0.00	0.06
Saccharum spp.	Monocot	Grass	12.05	12.33	11.06
Hemarthria compressa (L.f.) R.Br.	Monocot	Grass	7.35	7.37	7.27
Echinochloa crus-galli (L.) P.Beauv.	Monocot	Grass	6.94	6.94	6.91
Carex vesicaria L.	Monocot	Sedge	5.76	5.73	5.87
Cynodon dactylon (L.) Pers.	Monocot	Grass	5.13	5.16	5.01
Kyllinga brevifolia Rottb.	Monocot	Sedge	2.54	2.10	4.03
Alpinia nigra (Gaertn.) Burtt	Monocot	Herb	2.43	2.35	2.69
Imperata cylindrica (L.) Raeusch.	Monocot	Grass	2.33	2.33	2.32
Fimbristylis aestivalis Vahl	Monocot	Sedge	2.22	1.86	3.48
Setaria pumila (Poir.) Roem. & Schult.	Monocot	Grass	1.58	1.61	1.47
Eleusine indica (L.) Gaertn.	Monocot	Grass	1.12	1.10	1.22
Paspalum conjugatum P.J.Bergius	Monocot	Grass	0.78	0.71	1.04
Fimbristylis dichotoma (L.) Vahl	Monocot	Sedge	0.56	0.53	0.67
Cyrtococcum sp.	Monocot	Grass	0.56	0.62	0.37
Chrysopogon aciculatus (Retz.) Trin.	Monocot	Grass	0.41	0.32	0.73
Eleocharis acutangula (Roxb.) Schult.	Monocot	Sedge	0.34	0.41	0.12
*Oplismenus*sp.	Monocot	Grass	0.30	0.35	0.12
Setaria sp.	Monocot	Grass	0.23	0.12	0.61
Panicum sp.	Monocot	Grass	0.19	0.18	0.24
Identified Monocot (%)			**52.82**	**52.11**	**55.26**

Asiatic Wild Buffalo					
Plant species	**Monocot/ Dicot**	**Growth form**	**Percentage of occurrence (%)**		
			Overall (n=7)	**Season**	
				Dry (n=5)	**Wet (n=2)**
Unidentified Monocot (%)			**9.79**	**9.40**	**11.12**
Total Monocot (%)			**62.60**	**61.51**	**66.38**
Identified Dicot (%)			**34.96**	**35.75**	**32.21**
Unidentified Dicot (%)			**2.44**	**2.74**	**1.41**
Total Dicot (%)			**37.40**	**38.49**	**33.62**
Total (%)			**100.00**	**100.00**	**100.00**

n- number of months

Appendix 13. Diet composition (percentage of occurrence) of swamp deer (*Rucervus duvaucelii*) during 2013-15 in Kaziranga National Park, Assam.

Swamp Deer					
Plant species	**Monocot/ Dicot**	**Growth form**	**Percentage of occurrence (%)**		
			Overall (n=7)	**Season**	
				Dry (n=5)	**Wet (n=2)**
Ziziphus jujuba Mill.	Dicot	Tree	5.10	5.15	4.94
Acmella uliginosa (Sw.) Cass.	Dicot	Herb	2.33	2.45	1.96
Lippia alba (Mill.) N.E.Br. ex Britton & P.Wilson	Dicot	Shrub	2.18	2.38	1.59
Solanum americanum Mill.	Dicot	Herb	1.87	1.81	2.07
Oxalis corniculata L.	Dicot	Herb	1.62	1.47	2.07
Polygonum plebeium R.Br.	Dicot	Herb	1.61	1.50	1.91
Persicaria hydropiper (L.) Delarbre	Dicot	Herb	1.53	1.43	1.80
Melilotus albus Medik.	Dicot	Herb	1.47	1.32	1.91
Chenopodium album L.	Dicot	Herb	1.43	1.25	1.96
Amaranthus viridis L.	Dicot	Herb	1.32	1.56	0.64
Mallotus nudiflorus (L.) Kulju & Welzen	Dicot	Tree	1.24	1.22	1.33
Duchesnea indica (Andrews) Focke	Dicot	Herb	1.00	1.04	0.90
Ranunculus sceleratus L.	Dicot	Herb	0.76	0.89	0.37
Leucas aspera (Willd.) Link	Dicot	Herb	0.75	0.80	0.58
Ludwigia adscendens (L.) H.Hara	Dicot	Herb	0.63	0.50	1.01
Acacia sp.	Dicot	Tree	0.63	0.66	0.53
Flemingia lineata (L.) Aiton	Dicot	Shrub	0.51	0.54	0.42
Oenanthe javanica (Blume) DC.	Dicot	Herb	0.48	0.34	0.90
Grangea maderaspatana (L.) Poir.	Dicot	Herb	0.43	0.38	0.58
Laphangium luteoalbum (L.) Tzvelev	Dicot	Herb	0.32	0.39	0.11
Pouzolzia zeylanica (L.) Benn. & R. Br.	Dicot	Herb	0.32	0.23	0.58
Nelsonia canescens (Lam.) Spreng.	Dicot	Herb	0.31	0.36	0.16
Cotula hemispherica (Roxb.) Raizada	Dicot	Herb	0.27	0.23	0.37
Solanum viarum Dunal	Dicot	Shrub	0.24	0.27	0.16
Merremia sp.	Dicot	Climber	0.21	0.21	0.21
Dalbergia sissoo DC.	Dicot	Tree	0.21	0.27	0.05
Litsea salicifolia (Roxburgh ex Nees) Hook. f.	Dicot	Shrub	0.17	0.16	0.21
Tetrastigma dubium (Lawson) Planch.	Dicot	Climber	0.12	0.16	0.00
Rungia pectinata (L.) Nees	Dicot	Herb	0.09	0.09	0.11
Rorippa indica (L.) Hiern	Dicot	Herb	0.08	0.05	0.16
Crotalaria albida Roth	Dicot	Shrub	0.07	0.04	0.16
Dillenia indica L.	Dicot	Tree	0.05	0.07	0.00
Hypericum sp.	Dicot	Shrub	0.04	0.05	0.00
Cannabis sativa L.	Dicot	Herb	0.03	0.04	0.00
Urena lobata L.	Dicot	Shrub	0.03	0.04	0.00
Amaranthus spinosus L.	Dicot	Herb	0.01	0.02	0.00
Xanthium strumarium L.	Dicot	Herb	0.01	0.00	0.05
Mikania micrantha Kunth	Dicot	Climber	0.01	0.00	0.05
Artemisia sp.	Dicot	Herb	0.01	0.02	0.00
Hemarthria compressa (L.f.) R.Br.	Monocot	Grass	9.95	10.68	7.80
Saccharum spp.	Monocot	Grass	9.62	10.12	8.12
Echinochloa crus-galli (L.) P.Beauv.	Monocot	Grass	6.66	6.42	7.38
Carex vesicaria L.	Monocot	Sedge	6.58	6.37	7.22
Imperata cylindrica (L.) Raeusch.	Monocot	Grass	5.23	4.83	6.42
Cynodon dactylon (L.) Pers.	Monocot	Grass	4.48	4.88	3.29

Swamp Deer					
Plant species	Monocot/ Dicot	Growth form	Percentage of occurrence (%)		
			Overall (n=7)	Season	
				Dry (n=5)	Wet (n=2)
Kyllinga brevifolia Rottb.	Monocot	Sedge	4.24	4.36	3.87
Fimbristylis aestivalis Vahl	Monocot	Sedge	2.92	3.00	2.65
Setaria pumila (Poir.) Roem. & Schult.	Monocot	Grass	1.83	1.79	1.96
Eleusine indica (L.) Gaertn.	Monocot	Grass	1.71	1.73	1.65
Eleocharis acutangula (Roxb.) Schult.	Monocot	Sedge	1.32	0.91	2.55
Alpinia nigra (Gaertn.) Burtt	Monocot	Herb	1.18	1.04	1.59
Paspalum conjugatum P.J.Bergius	Monocot	Grass	1.04	0.93	1.38
Chrysopogon aciculatus (Retz.) Trin.	Monocot	Grass	0.74	0.75	0.69
*Oplismenus*sp.	Monocot	Grass	0.43	0.29	0.85
Cyrtococcum sp.	Monocot	Grass	0.39	0.34	0.53
Fimbristylis dichotoma (L.) Vahl	Monocot	Sedge	0.25	0.11	0.69
Setaria sp.	Monocot	Grass	0.08	0.11	0.00
Panicum sp.	Monocot	Grass	0.04	0.05	0.00
Cyperus squarrosus L.	Monocot	Sedge	0.01	0.02	0.00
Identified Monocot (%)			**58.72**	**58.74**	**58.65**
Unidentified Monocot (%)			**9.66**	**9.68**	**9.61**
Total Monocot (%)			**68.37**	**68.41**	**68.26**
Identified Dicot (%)			**29.51**	**29.39**	**29.88**
Unidentified Dicot (%)			**2.11**	**2.20**	**1.86**
Total Dicot (%)			**31.63**	**31.59**	**31.74**
Total (%)			**100.00**	**100.00**	**100.00**

n- number of months

Appendix 14. Diet composition (percentage of occurrence) of hog deer (*Axis porcinus*) during 2013-15 in Kaziranga National Park, Assam.

Hog Deer					
Plant species	Monocot/ Dicot	Growth form	Percentage of occurrence (%)		
			Overall (n=7)	Season	
				Dry (n=5)	Wet (n=2)
Ziziphus jujuba Mill.	Dicot	Tree	6.22	6.69	4.55
Amaranthus viridis L.	Dicot	Herb	2.32	2.62	1.25
Duchesnea indica (Andrews) Focke	Dicot	Herb	2.16	2.35	1.49
Solanum americanum Mill.	Dicot	Herb	2.12	2.12	2.12
Lippia alba (Mill.) N.E.Br. ex Britton & P.Wilson	Dicot	Shrub	2.11	2.14	1.99
Acmella uliginosa (Sw.) Cass.	Dicot	Herb	2.02	2.12	1.68
Oxalis corniculata L.	Dicot	Herb	1.75	1.88	1.31
Tetrastigma dubium (Lawson) Planch.	Dicot	Climber	1.55	1.44	1.93
Mallotus nudiflorus (L.) Kulju & Welzen	Dicot	Tree	1.25	1.23	1.31
Acacia sp.	Dicot	Tree	1.20	1.32	0.75
Polygonum plebeium R.Br.	Dicot	Herb	1.18	1.20	1.12
Flemingia lineata (L.) Aiton	Dicot	Shrub	1.06	1.04	1.12
Melilotus albus Medik.	Dicot	Herb	0.98	1.11	0.50
Persicaria hydropiper (L.) Delarbre	Dicot	Herb	0.88	0.96	0.62
Hypericum sp.	Dicot	Shrub	0.73	0.43	1.81
Dillenia indica L.	Dicot	Tree	0.71	0.75	0.56
Nelsonia canescens (Lam.) Spreng.	Dicot	Herb	0.69	0.71	0.62
Leucas aspera (Willd.) Link	Dicot	Herb	0.67	0.63	0.81
Chenopodium album L.	Dicot	Herb	0.61	0.75	0.12
Grangea maderaspatana (L.) Poir.	Dicot	Herb	0.53	0.31	1.31
Oenanthe javanica (Blume) DC.	Dicot	Herb	0.45	0.45	0.44
Ageratum conyzoides (L.) L.	Dicot	Herb	0.43	0.52	0.12

Hog Deer					
Plant species	**Monocot/ Dicot**	**Growth form**	**Percentage of occurrence (%)**		
			Overall (n=7)	**Season**	
				Dry (n=5)	**Wet (n=2)**
Laphangium luteoalbum (L.) Tzvelev	Dicot	Herb	0.38	0.37	0.44
Dalbergia sissoo DC.	Dicot	Tree	0.34	0.31	0.44
Pouzolzia zeylanica (L.) Benn. & R. Br.	Dicot	Herb	0.31	0.38	0.06
Crotalaria albida Roth	Dicot	Shrub	0.30	0.37	0.06
Solanum viarum Dunal	Dicot	Shrub	0.29	0.30	0.25
Urena lobata L.	Dicot	Shrub	0.24	0.30	0.06
Cannabis sativa L.	Dicot	Herb	0.24	0.30	0.06
Ranunculus sceleratus L.	Dicot	Herb	0.18	0.19	0.12
Rungia pectinata (L.) Nees	Dicot	Herb	0.15	0.16	0.12
Litsea salicifolia (Roxburgh ex Nees) Hook. f.	Dicot	Shrub	0.15	0.12	0.25
Amaranthus spinosus L.	Dicot	Herb	0.14	0.17	0.00
Cajanus scarabaeoides (L.) Thouars	Dicot	Climber	0.14	0.16	0.06
Mikania micrantha Kunth	Dicot	Climber	0.12	0.10	0.19
Merremia sp.	Dicot	Climber	0.11	0.07	0.25
Ludwigia adscendens (L.) H.Hara	Dicot	Herb	0.05	0.03	0.12
Cotula hemispherica (Roxb.) Raizada	Dicot	Herb	0.04	0.03	0.06
Youngia japonica (L.) DC.	Dicot	Herb	0.03	0.03	0.00
Merremia umbellata (L.) Hallier f.	Dicot	Climber	0.01	0.02	0.00
Hemarthria compressa (L.f.) R.Br.	Monocot	Grass	9.96	9.32	12.27
Saccharum spp.	Monocot	Grass	9.35	8.13	13.70
Echinochloa crus-galli (L.) P.Beauv.	Monocot	Grass	6.81	7.13	5.67
Carex vesicaria L.	Monocot	Sedge	5.88	6.05	5.29
Cynodon dactylon (L.) Pers.	Monocot	Grass	4.95	5.21	3.99
Kyllinga brevifolia Rottb.	Monocot	Sedge	3.04	3.13	2.74
Fimbristylis aestivalis Vahl	Monocot	Sedge	2.11	2.03	2.37
Setaria pumila (Poir.) Roem. & Schult.	Monocot	Grass	2.09	2.16	1.87
Imperata cylindrica (L.) Raeusch.	Monocot	Grass	1.86	1.72	2.37
Alpinia nigra (Gaertn.) Burtt	Monocot	Herb	1.82	1.79	1.93
Eleusine indica (L.) Gaertn.	Monocot	Grass	1.17	1.10	1.43
Paspalum conjugatum P.J.Bergius	Monocot	Grass	0.90	0.97	0.62
Eleocharis acutangula (Roxb.) Schult.	Monocot	Sedge	0.77	0.76	0.81
Chrysopogon aciculatus (Retz.) Trin.	Monocot	Grass	0.46	0.52	0.25
Panicum sp.	Monocot	Grass	0.31	0.33	0.25
Cyrtococcum sp.	Monocot	Grass	0.31	0.33	0.25
Setaria sp.	Monocot	Grass	0.24	0.21	0.37
*Oplismenus*sp.	Monocot	Grass	0.20	0.16	0.37
Fimbristylis dichotoma (L.) Vahl	Monocot	Sedge	0.12	0.16	0.00
Identified Monocot (%)			**52.37**	**51.21**	**56.54**
Unidentified Monocot (%)			**10.52**	**10.34**	**11.15**
Total Monocot (%)			**62.89**	**61.55**	**67.68**
Identified Dicot (%)			**34.86**	**36.19**	**30.07**
Unidentified Dicot (%)			**2.26**	**2.26**	**2.24**
Total Dicot (%)			**37.11**	**38.45**	**32.32**
Total (%)			**100.00**	**100.00**	**100.00**

n- number of months

Appendix 15. Diet composition (percentage of occurrence) of sambar (*Rusa unicolor*) during 2013-15 in Kaziranga National Park, Assam.

Sambar					
Plant species	Monocot/ Dicot	Growth form	Percentage of occurrence (%)		
			Overall (n=7)	Season	
				Dry (n=5)	Wet (n=2)
Ziziphus jujuba Mill.	Dicot	Tree	7.59	8.05	5.16
Acmella uliginosa (Sw.) Cass.	Dicot	Herb	2.69	2.82	1.96
Solanum americanum Mill.	Dicot	Herb	2.57	2.62	2.32
Dillenia indica L.	Dicot	Tree	2.33	2.50	1.42
Mallotus nudiflorus (L.) Kulju & Welzen	Dicot	Tree	2.09	2.20	1.51
Lippia alba (Mill.) N.E.Br. ex Britton & P.Wilson	Dicot	Shrub	2.05	2.25	0.98
Melilotus albus Medik.	Dicot	Herb	1.95	2.01	1.60
Chenopodium album L.	Dicot	Herb	1.93	2.15	0.80
Amaranthus viridis L.	Dicot	Herb	1.78	1.84	1.42
Ageratum conyzoides (L.) L.	Dicot	Herb	1.65	1.83	0.71
Tetrastigma dubium (Lawson) Planch.	Dicot	Climber	1.65	1.78	0.98
Acacia sp.	Dicot	Tree	1.48	1.44	1.69
Duchesnea indica (Andrews) Focke	Dicot	Herb	1.45	1.59	0.71
Nelsonia canescens (Lam.) Spreng.	Dicot	Herb	1.44	1.62	0.45
Hypericum sp.	Dicot	Shrub	1.32	1.35	1.16
Urena lobata L.	Dicot	Shrub	1.32	1.39	0.98
Merremia sp.	Dicot	Climber	1.25	1.32	0.89
Leucas aspera (Willd.) Link	Dicot	Herb	1.21	1.22	1.16
Persicaria hydropiper (L.) Delarbre	Dicot	Herb	1.08	1.10	0.98
Polygonum plebeium R.Br.	Dicot	Herb	0.74	0.79	0.45
Oenanthe javanica (Blume) DC.	Dicot	Herb	0.71	0.79	0.27
Crotalaria albida Roth	Dicot	Shrub	0.70	0.78	0.27
Pouzolzia zeylanica (L.) Benn. & R. Br.	Dicot	Herb	0.53	0.61	0.09
Laphangium luteoalbum (L.) Tzvelev	Dicot	Herb	0.50	0.49	0.53
Amaranthus spinosus L.	Dicot	Herb	0.48	0.46	0.62
Dalbergia sissoo DC.	Dicot	Tree	0.47	0.52	0.18
Ludwigia adscendens (L.) H.Hara	Dicot	Herb	0.43	0.44	0.36
Oxalis corniculata L.	Dicot	Herb	0.43	0.44	0.36
Cannabis sativa L.	Dicot	Herb	0.36	0.36	0.36
Flemingia lineata (L.) Aiton	Dicot	Shrub	0.33	0.34	0.27
Grangea maderaspatana (L.) Poir.	Dicot	Herb	0.31	0.37	0.00
Litsea salicifolia (Roxburgh ex Nees) Hook. f.	Dicot	Shrub	0.23	0.25	0.09
Ranunculus sceleratus L.	Dicot	Herb	0.23	0.25	0.09
Glochidion multiloculare (Rottler ex Willd.) Voigt	Dicot	Shrub	0.18	0.15	0.36
Flueggea virosa (Roxb. ex Willd.) Royl	Dicot	Shrub	0.18	0.15	0.36
Solanum viarum Dunal	Dicot	Shrub	0.18	0.20	0.09
Mikania micrantha Kunth	Dicot	Climber	0.17	0.19	0.09
Cotula hemispherica (Roxb.) Raizada	Dicot	Herb	0.09	0.08	0.09
Youngia japonica (L.) DC.	Dicot	Herb	0.06	0.07	0.00
Rungia pectinata (L.) Nees	Dicot	Herb	0.04	0.03	0.09
Rorippa indica (L.) Hiern	Dicot	Herb	0.04	0.05	0.00
Cajanus scarabaeoides (L.) Thouars	Dicot	Climber	0.03	0.03	0.00
Cleome spinosa Jacq.	Dicot	Herb	0.01	0.02	0.00
Rumex dentatus L.	Dicot	Herb	0.01	0.02	0.00
Stachytarpheta indica (L.) Vahl	Dicot	Shrub	0.01	0.02	0.00
Saccharum spp.	Monocot	Grass	13.40	12.44	18.43
Echinochloa crus-galli (L.) P.Beauv.	Monocot	Grass	5.23	5.09	5.97

Sambar					
Plant species	**Monocot/ Dicot**	**Growth form**	**Percentage of occurrence (%)**		
			Overall (n=7)	**Season**	
				Dry (n=5)	**Wet (n=2)**
Hemarthria compressa (L.f.) R.Br.	Monocot	Grass	4.97	4.82	5.79
Carex vesicaria L.	Monocot	Sedge	4.66	4.14	7.39
Imperata cylindrica (L.) Raeusch.	Monocot	Grass	2.20	1.99	3.29
Kyllinga brevifolia Rottb.	Monocot	Sedge	2.13	2.01	2.76
Cynodon dactylon (L.) Pers.	Monocot	Grass	1.95	1.99	1.69
Fimbristylis aestivalis Vahl	Monocot	Sedge	1.86	1.96	1.34
Alpinia nigra (Gaertn.) Burtt	Monocot	Herb	1.75	1.72	1.87
Chrysopogon aciculatus (Retz.) Trin.	Monocot	Grass	1.17	1.10	1.51
Setaria pumila (Poir.) Roem. & Schult.	Monocot	Grass	1.17	1.12	1.42
Eleocharis acutangula (Roxb.) Schult.	Monocot	Sedge	1.05	0.81	2.32
Eleusine indica (L.) Gaertn.	Monocot	Grass	0.54	0.46	0.98
Paspalum conjugatum P.J.Bergius	Monocot	Grass	0.38	0.41	0.27
Cyrtococcum sp.	Monocot	Grass	0.30	0.19	0.89
Fimbristylis dichotoma (L.) Vahl	Monocot	Sedge	0.11	0.03	0.53
Setaria sp.	Monocot	Grass	0.04	0.05	0.00
*Oplismenus*sp.	Monocot	Grass	0.03	0.03	0.00
Identified Monocot (%)			**42.94**	**40.37**	**56.46**
Unidentified Monocot (%)			**8.53**	**8.23**	**10.06**
Total Monocot (%)			**51.46**	**48.61**	**66.52**
Identified Dicot (%)			**46.25**	**48.98**	**31.88**
Unidentified Dicot (%)			**2.29**	**2.42**	**1.60**
Total Dicot (%)			**48.54**	**51.39**	**33.48**
Total (%)			**100.00**	**100.00**	**100.00**

n- number of months

Appendix 16. Jacob's index of forage species preferred and avoided by rhino in Kaziranga National Park, Assam.

Season	**Plant species**	**U**	**A**	**JI**	**BI (90% CI)**
Overall	*Alpinia nigra* (Gaertn.) Burtt	0.11	0.02	0.66	0.107 ≤ p ≤ 0.112**
Overall	*Carex vesicaria* L.	0.10	0.12	-0.08	0.102 ≤ p ≤ 0.106*
Overall	*Cynodon dactylon* (L.) Pers.	0.15	0.09	0.30	0.151 ≤ p ≤ 0.157**
Overall	*Flemingia lineata* (L.) Aiton	0.03	0.01	0.63	0.024 ≤ p ≤ 0.027**
Overall	*Hemarthria compressa* (L.f.) R.Br.	0.14	0.17	-0.13	0.134 ≤ p ≤ 0.139*
Overall	*Litsea salicifolia* (Roxburgh ex Nees) Hook. f.	0.01	0.01	0.25	0.009 ≤ p ≤ 0.011**
Overall	*Merremia umbellata* (L.) Hallier f.		0.02	-1.00	
Overall	*Mikania micrantha* Kunth	0.03	0.01	0.70	0.032 ≤ p ≤ 0.034**
Overall	*Mimosa* spp.	0.00	0.01	-0.33	0.004 ≤ p ≤ 0.005*
Overall	*Paspalum conjugatum* P.J.Bergius	0.03	0.01	0.52	0.029 ≤ p ≤ 0.032**
Overall	*Saccharum* spp.	0.39	0.51	-0.23	0.389 ≤ p ≤ 0.397*
Dry	*Alpinia nigra* (Gaertn.) Burtt	0.12	0.03	0.61	0.119 ≤ p ≤ 0.123**
Dry	*Carex vesicaria* L.	0.09	0.11	-0.08	0.09 ≤ p ≤ 0.094**
Dry	*Cynodon dactylon* (L.) Pers.	0.16	0.10	0.26	0.157 ≤ p ≤ 0.162**
Dry	*Flemingia lineata* (L.) Aiton	0.03	0.01	0.54	0.026 ≤ p ≤ 0.028**
Dry	*Hemarthria compressa* (L.f.) R.Br.	0.13	0.17	-0.15	0.131 ≤ p ≤ 0.136*
Dry	*Litsea salicifolia* (Roxburgh ex Nees) Hook. f.	0.01	0.01	0.25	0.011 ≤ p ≤ 0.013**
Dry	*Merremia umbellata* (L.) Hallier f.	0.00	0.03	-1.00	
Dry	*Mikania micrantha* Kunth	0.04	0.01	0.61	0.04 ≤ p ≤ 0.043**
Dry	*Mimosa* spp.	0.00	0.01	-0.56	0.002 ≤ p ≤ 0.003*
Dry	*Paspalum conjugatum* P.J.Bergius	0.02	0.01	0.39	0.023 ≤ p ≤ 0.025**
Dry	*Saccharum* spp.	0.39	0.48	-0.20	0.384 ≤ p ≤ 0.391*
Wet	*Alpinia nigra* (Gaertn.) Burtt	0.09	0.05	0.30	0.085 ≤ p ≤ 0.089**
Wet	*Carex vesicaria* L.	0.13	0.08	0.28	0.126 ≤ p ≤ 0.131**
Wet	*Cynodon dactylon* (L.) Pers.	0.14	0.12	0.08	0.14 ≤ p ≤ 0.146**

Season	Plant species	U	A	JI	BI (90% CI)
Wet	*Flemingia lineata* (L.) Aiton	0.02	0.01	0.25	0.021 ≤ p ≤ 0.024**
Wet	*Hemarthria compressa* (L.f.) R.Br.	0.14	0.18	-0.15	0.139 ≤ p ≤ 0.144*
Wet	*Litsea salicifolia* (Roxburgh ex Nees) Hook. f.	0.01	0.01	-0.29	0.005 ≤ p ≤ 0.006*
Wet	*Merremia umbellata* (L.) Hallier f.		0.04	-1.00	
Wet	*Mikania micrantha* Kunth	0.02	0.02	-0.13	0.015 ≤ p ≤ 0.017**
Wet	*Mimosa* spp.	0.01	0.01	-0.21	0.007 ≤ p ≤ 0.009*
Wet	*Paspalum conjugatum* P.J.Bergius	0.04	0.01	0.57	0.042 ≤ p ≤ 0.045**
Wet	*Saccharum* spp.	0.40	0.43	-0.06	0.401 ≤ p ≤ 0.408*

U- used proportion, A- available proportion, JI- Jacob's Index, BI- Boneferroni confidence interval on used proportion of forage species (90% confidence coefficient), *- significant differences at 0.10 significance level where forage species used less than its availability, **- significant differences at 0.10 significance level where forage species used more than its availability

Appendix 17. Jacob's index of forage species preferred and avoided by elephant in Kaziranga National Park, Assam.

Season	Plant species	U	A	JI	BI (90% CI)
Overall	*Alpinia nigra* (Gaertn.) Burtt	0.09	0.02	0.61	0.09 ≤ p ≤ 0.095**
Overall	*Carex vesicaria* L.	0.13	0.12	0.04	0.125 ≤ p ≤ 0.13**
Overall	*Cynodon dactylon* (L.) Pers.	0.08	0.09	-0.07	0.076 ≤ p ≤ 0.08*
Overall	*Flemingia lineata* (L.) Aiton	0.03	0.01	0.69	0.03 ≤ p ≤ 0.032**
Overall	*Hemarthria compressa* (L.f.) R.Br.	0.11	0.17	-0.25	0.106 ≤ p ≤ 0.11*
Overall	*Litsea salicifolia* (Roxburgh ex Nees) Hook. f.	0.04	0.01	0.76	0.041 ≤ p ≤ 0.044**
Overall	*Merremia umbellata* (L.) Hallier f.		0.02	-1.00	
Overall	*Mikania micrantha* Kunth	0.03	0.01	0.63	0.024 ≤ p ≤ 0.027**
Overall	*Mimosa* spp.	0.00	0.01	-0.75	0.001 ≤ p ≤ 0.002*
Overall	*Paspalum conjugatum* P.J.Bergius	0.02	0.01	0.42	0.022 ≤ p ≤ 0.025**
Overall	*Saccharum* spp.	0.47	0.51	-0.08	0.466 ≤ p ≤ 0.473*
Dry	*Alpinia nigra* (Gaertn.) Burtt	0.12	0.03	0.62	0.119 ≤ p ≤ 0.124**
Dry	*Carex vesicaria* L.	0.11	0.11	0.04	0.112 ≤ p ≤ 0.117**
Dry	*Cynodon dactylon* (L.) Pers.	0.08	0.10	-0.14	0.076 ≤ p ≤ 0.08*
Dry	*Flemingia lineata* (L.) Aiton	0.04	0.01	0.67	0.04 ≤ p ≤ 0.043**
Dry	*Hemarthria compressa* (L.f.) R.Br.	0.09	0.17	-0.37	0.086 ≤ p ≤ 0.09*
Dry	*Litsea salicifolia* (Roxburgh ex Nees) Hook. f.	0.05	0.01	0.76	0.051 ≤ p ≤ 0.054**
Dry	*Merremia umbellata* (L.) Hallier f.		0.03	-1.00	
Dry	*Mikania micrantha* Kunth	0.03	0.01	0.55	0.033 ≤ p ≤ 0.036**
Dry	*Mimosa* spp.	0.00	0.01	-0.67	0.002 ≤ p ≤ 0.002*
Dry	*Paspalum conjugatum* P.J.Bergius	0.03	0.01	0.49	0.029 ≤ p ≤ 0.031**
Dry	*Saccharum* spp.	0.44	0.48	-0.10	0.434 ≤ p ≤ 0.441*
Wet	*Alpinia nigra* (Gaertn.) Burtt	0.04	0.05	-0.08	0.04 ≤ p ≤ 0.043**
Wet	*Carex vesicaria* L.	0.15	0.08	0.36	0.149 ≤ p ≤ 0.154**
Wet	*Cynodon dactylon* (L.) Pers.	0.08	0.12	-0.25	0.077 ≤ p ≤ 0.08*
Wet	*Flemingia lineata* (L.) Aiton	0.01	0.01	-0.04	0.012 ≤ p ≤ 0.014**
Wet	*Hemarthria compressa* (L.f.) R.Br.	0.14	0.18	-0.15	0.141 ≤ p ≤ 0.146*
Wet	*Litsea salicifolia* (Roxburgh ex Nees) Hook. f.	0.03	0.01	0.43	0.024 ≤ p ≤ 0.027**
Wet	*Merremia umbellata* (L.) Hallier f.		0.04	-1.00	
Wet	*Mikania micrantha* Kunth	0.01	0.02	-0.38	0.009 ≤ p ≤ 0.01**
Wet	*Mimosa* spp.		0.01	-1.00	
Wet	*Paspalum conjugatum* P.J.Bergius	0.01	0.01	-0.04	0.011 ≤ p ≤ 0.012**
Wet	*Saccharum* spp.	0.53	0.43	0.19	0.523 ≤ p ≤ 0.53

U- used proportion, A- available proportion, JI- Jacob's Index, BI- Boneferroni confidence interval on used proportion of forage species (90% confidence coefficient), *- significant differences at 0.10 significance level where forage species used less than its availability, **- significant differences at 0.10 significance level where forage species used more than its availability

Appendix 18. Jacob's index of forage species preferred and avoided by buffalo in Kaziranga National Park, Assam.

Season	Plant species	U	A	JI	BI (90% CI)
Overall	*Alpinia nigra* (Gaertn.) Burtt	0.07	0.02	0.49	0.066 ≤ p ≤ 0.069**
Overall	*Carex vesicaria* L.	0.16	0.12	0.17	0.157 ≤ p ≤ 0.163**
Overall	*Cynodon dactylon* (L.) Pers.	0.14	0.09	0.26	0.14 ≤ p ≤ 0.145**
Overall	*Flemingia lineata* (L.) Aiton	0.03	0.01	0.62	0.024 ≤ p ≤ 0.026**
Overall	*Hemarthria compressa* (L.f.) R.Br.	0.20	0.17	0.12	0.201 ≤ p ≤ 0.207**
Overall	*Litsea salicifolia* (Roxburgh ex Nees) Hook. f.	0.01	0.01	0.40	0.013 ≤ p ≤ 0.015**

Season	Plant species	U	A	JI	BI (90% CI)
Overall	*Merremia umbellata* (L.) Hallier f.		0.02	-1.00	
Overall	*Mikania micrantha* Kunth	0.03	0.01	0.66	0.027 ≤ p ≤ 0.03**
Overall	*Mimosa* spp.	0.00	0.01	-0.77	0.001 ≤ p ≤ 0.001*
Overall	*Paspalum conjugatum* P.J.Bergius	0.02	0.01	0.39	0.021 ≤ p ≤ 0.023**
Overall	*Saccharum* spp.	0.33	0.51	-0.35	0.332 ≤ p ≤ 0.338*
Dry	*Alpinia nigra* (Gaertn.) Burtt	0.06	0.03	0.36	0.063 ≤ p ≤ 0.066**
Dry	*Carex vesicaria* L.	0.16	0.11	0.22	0.155 ≤ p ≤ 0.16**
Dry	*Cynodon dactylon* (L.) Pers.	0.14	0.10	0.19	0.139 ≤ p ≤ 0.145**
Dry	*Flemingia lineata* (L.) Aiton	0.03	0.01	0.56	0.028 ≤ p ≤ 0.03**
Dry	*Hemarthria compressa* (L.f.) R.Br.	0.20	0.17	0.10	0.2 ≤ p ≤ 0.206**
Dry	*Litsea salicifolia* (Roxburgh ex Nees) Hook. f.	0.01	0.01	0.32	0.013 ≤ p ≤ 0.015**
Dry	*Merremia umbellata* (L.) Hallier f.		0.03	-1.00	
Dry	*Mikania micrantha* Kunth	0.03	0.01	0.49	0.028 ≤ p ≤ 0.031**
Dry	*Mimosa* spp.	0.00	0.01	-0.82	0.001 ≤ p ≤ 0.001*
Dry	*Paspalum conjugatum* P.J.Bergius	0.02	0.01	0.30	0.018 ≤ p ≤ 0.02**
Dry	*Saccharum* spp.	0.34	0.48	-0.29	0.336 ≤ p ≤ 0.343*
Wet	*Alpinia nigra* (Gaertn.) Burtt	0.08	0.05	0.24	0.075 ≤ p ≤ 0.079**
Wet	*Carex vesicaria* L.	0.17	0.08	0.42	0.166 ≤ p ≤ 0.172**
Wet	*Cynodon dactylon* (L.) Pers.	0.14	0.12	0.09	0.142 ≤ p ≤ 0.147**
Wet	*Flemingia lineata* (L.) Aiton	0.01	0.01	-0.13	0.01 ≤ p ≤ 0.011**
Wet	*Hemarthria compressa* (L.f.) R.Br.	0.21	0.18	0.08	0.207 ≤ p ≤ 0.213**
Wet	*Litsea salicifolia* (Roxburgh ex Nees) Hook. f.	0.01	0.01	0.16	0.013 ≤ p ≤ 0.015**
Wet	*Merremia umbellata* (L.) Hallier f.		0.04	-1.00	
Wet	*Mikania micrantha* Kunth	0.02	0.02	0.10	0.024 ≤ p ≤ 0.026**
Wet	*Mimosa* spp.	0.00	0.01	-0.75	0.001 ≤ p ≤ 0.002*
Wet	*Paspalum conjugatum* P.J.Bergius	0.03	0.01	0.42	0.029 ≤ p ≤ 0.031**
Wet	*Saccharum* spp.	0.32	0.43	-0.24	0.315 ≤ p ≤ 0.322*

U- used proportion, A- available proportion, JI- Jacob's Index, BI- Boneferroni confidence interval on used proportion of forage species (90% confidence coefficient), *- significant differences at 0.10 significance level where forage species used less than its availability, **- significant differences at 0.10 significance level where forage species used more than its availability

Appendix 19. Jacob's index of forage species preferred and avoided by swamp deer in Kaziranga National Park, Assam.

Season	Plant species	U	A	JI	BI (90% CI)
Overall	*Alpinia nigra* (Gaertn.) Burtt	0.04	0.02	0.19	0.034 ≤ p ≤ 0.036**
Overall	*Carex vesicaria* L.	0.20	0.12	0.28	0.193 ≤ p ≤ 0.199**
Overall	*Cynodon dactylon* (L.) Pers.	0.13	0.09	0.22	0.131 ≤ p ≤ 0.136**
Overall	*Flemingia lineata* (L.) Aiton	0.02	0.01	0.44	0.014 ≤ p ≤ 0.016**
Overall	*Hemarthria compressa* (L.f.) R.Br.	0.30	0.17	0.35	0.293 ≤ p ≤ 0.3**
Overall	*Litsea salicifolia* (Roxburgh ex Nees) Hook. f.	0.01	0.01	-0.08	0.005 ≤ p ≤ 0.006*
Overall	*Merremia umbellata* (L.) Hallier f.		0.02	-1.00	
Overall	*Mikania micrantha* Kunth	0.00	0.01	-0.87	0 ≤ p ≤ 0.001*
Overall	*Mimosa* spp.		0.01	-1.00	
Overall	*Paspalum conjugatum* P.J.Bergius	0.03	0.01	0.53	0.03 ≤ p ≤ 0.032**
Overall	*Saccharum* spp.	0.29	0.51	-0.44	0.283 ≤ p ≤ 0.29*
Dry	*Alpinia nigra* (Gaertn.) Burtt	0.03	0.03	-0.03	0.029 ≤ p ≤ 0.031*
Dry	*Carex vesicaria* L.	0.18	0.11	0.31	0.181 ≤ p ≤ 0.186**
Dry	*Cynodon dactylon* (L.) Pers.	0.14	0.10	0.19	0.138 ≤ p ≤ 0.143**
Dry	*Flemingia lineata* (L.) Aiton	0.02	0.01	0.30	0.015 ≤ p ≤ 0.016**
Dry	*Hemarthria compressa* (L.f.) R.Br.	0.31	0.17	0.36	0.304 ≤ p ≤ 0.311**
Dry	*Litsea salicifolia* (Roxburgh ex Nees) Hook. f.	0.00	0.01	-0.23	0.004 ≤ p ≤ 0.005*
Dry	*Merremia umbellata* (L.) Hallier f.		0.03	-1.00	
Dry	*Mikania micrantha* Kunth		0.01	-1.00	
Dry	*Mimosa* spp.		0.01	-1.00	
Dry	*Paspalum conjugatum* P.J.Bergius	0.03	0.01	0.44	0.026 ≤ p ≤ 0.028**
Dry	*Saccharum* spp.	0.29	0.48	-0.39	0.288 ≤ p ≤ 0.295*
Wet	*Alpinia nigra* (Gaertn.) Burtt	0.05	0.05	0.04	0.051 ≤ p ≤ 0.055**
Wet	*Carex vesicaria* L.	0.24	0.08	0.58	0.237 ≤ p ≤ 0.243**
Wet	*Cynodon dactylon* (L.) Pers.	0.11	0.12	-0.07	0.107 ≤ p ≤ 0.112**
Wet	*Flemingia lineata* (L.) Aiton	0.01	0.01	0.02	0.013 ≤ p ≤ 0.015**
Wet	*Hemarthria compressa* (L.f.) R.Br.	0.26	0.18	0.22	0.256 ≤ p ≤ 0.262**
Wet	*Litsea salicifolia* (Roxburgh ex Nees) Hook. f.	0.01	0.01	-0.19	0.006 ≤ p ≤ 0.008**
Wet	*Merremia umbellata* (L.) Hallier f.		0.04	-1.00	
Wet	*Mikania micrantha* Kunth	0.00	0.02	-0.84	0.001 ≤ p ≤ 0.002*
Wet	*Mimosa* spp.		0.01	-1.00	

Season	Plant species	U	A	JI	BI (90% CI)
Wet	*Paspalum conjugatum* P.J.Bergius	0.05	0.01	0.59	0.044 ≤ p ≤ 0.047**
Wet	*Saccharum* spp.	0.27	0.43	-0.35	0.267 ≤ p ≤ 0.273*

U- used proportion, A- available proportion, JI- Jacob's Index, BI- Boneferroni confidence interval on used proportion of forage species (90% confidence coefficient), *- significant differences at 0.10 significance level where forage species used less than its availability, **- significant differences at 0.10 significance level where forage species used more than its availability

Appendix 20. Jacob's index of forage species preferred and avoided by hog deer in Kaziranga National Park, Assam.

Season	Plant species	U	A	JI	BI (90% CI)
Overall	*Alpinia nigra* (Gaertn.) Burtt	0.05	0.02	0.39	0.052 ≤ p ≤ 0.055**
Overall	*Carex vesicaria* L.	0.17	0.12	0.21	0.169 ≤ p ≤ 0.175**
Overall	*Cynodon dactylon* (L.) Pers.	0.14	0.09	0.26	0.142 ≤ p ≤ 0.147**
Overall	*Flemingia lineata* (L.) Aiton	0.03	0.01	0.69	0.03 ≤ p ≤ 0.032**
Overall	*Hemarthria compressa* (L.f.) R.Br.	0.29	0.17	0.34	0.288 ≤ p ≤ 0.295**
Overall	*Litsea salicifolia* (Roxburgh ex Nees) Hook. f.	0.00	0.01	-0.16	0.004 ≤ p ≤ 0.005*
Overall	*Merremia umbellata* (L.) Hallier f.	0.00	0.02	-0.97	0 ≤ p ≤ 0.001*
Overall	*Mikania micrantha* Kunth	0.00	0.01	-0.25	0.003 ≤ p ≤ 0.004*
Overall	*Mimosa* spp.		0.01	-1.00	
Overall	*Paspalum conjugatum* P.J.Bergius	0.03	0.01	0.47	0.025 ≤ p ≤ 0.027**
Overall	*Saccharum* spp.	0.27	0.51	-0.47	0.27 ≤ p ≤ 0.277*
Dry	*Alpinia nigra* (Gaertn.) Burtt	0.05	0.03	0.28	0.053 ≤ p ≤ 0.056**
Dry	*Carex vesicaria* L.	0.18	0.11	0.31	0.182 ≤ p ≤ 0.187**
Dry	*Cynodon dactylon* (L.) Pers.	0.16	0.10	0.26	0.156 ≤ p ≤ 0.162**
Dry	*Flemingia lineata* (L.) Aiton	0.03	0.01	0.59	0.031 ≤ p ≤ 0.033**
Dry	*Hemarthria compressa* (L.f.) R.Br.	0.28	0.17	0.31	0.281 ≤ p ≤ 0.288**
Dry	*Litsea salicifolia* (Roxburgh ex Nees) Hook. f.	0.00	0.01	-0.33	0.003 ≤ p ≤ 0.004*
Dry	*Merremia umbellata* (L.) Hallier f.	0.00	0.03	-0.96	0 ≤ p ≤ 0.001*
Dry	*Mikania micrantha* Kunth	0.00	0.01	-0.53	0.003 ≤ p ≤ 0.004*
Dry	*Mimosa* spp.		0.01	-1.00	
Dry	*Paspalum conjugatum* P.J.Bergius	0.03	0.01	0.48	0.028 ≤ p ≤ 0.031**
Dry	*Saccharum* spp.	0.25	0.48	-0.48	0.245 ≤ p ≤ 0.251*
Wet	*Alpinia nigra* (Gaertn.) Burtt	0.05	0.05	0.00	0.047 ≤ p ≤ 0.051**
Wet	*Carex vesicaria* L.	0.13	0.08	0.30	0.132 ≤ p ≤ 0.137**
Wet	*Cynodon dactylon* (L.) Pers.	0.10	0.12	-0.12	0.099 ≤ p ≤ 0.103**
Wet	*Flemingia lineata* (L.) Aiton	0.03	0.01	0.36	0.027 ≤ p ≤ 0.03**
Wet	*Hemarthria compressa* (L.f.) R.Br.	0.31	0.18	0.34	0.308 ≤ p ≤ 0.315**
Wet	*Litsea salicifolia* (Roxburgh ex Nees) Hook. f.	0.01	0.01	-0.24	0.006 ≤ p ≤ 0.007
Wet	*Merremia umbellata* (L.) Hallier f.		0.04	-1.00	
Wet	*Mikania micrantha* Kunth	0.00	0.02	-0.62	0.004 ≤ p ≤ 0.005*
Wet	*Mimosa* spp.		0.01	-1.00	
Wet	*Paspalum conjugatum* P.J.Bergius	0.02	0.01	0.12	0.015 ≤ p ≤ 0.017**
Wet	*Saccharum* spp.	0.35	0.43	-0.17	0.345 ≤ p ≤ 0.352*

U- used proportion, A- available proportion, JI- Jacob's Index, BI- Boneferroni confidence interval on used proportion of forage species (90% confidence coefficient), *- significant differences at 0.10 significance level where forage species used less than its availability, **- significant differences at 0.10 significance level where forage species used more than its availability

Appendix 21. Jacob's index of forage species preferred and avoided by sambar in Kaziranga National Park, Assam.

Season	Plant species	U	A	JI	BI (90% CI)
Overall	*Alpinia nigra* (Gaertn.) Burtt	0.06	0.02	0.46	0.061 ≤ p ≤ 0.065**
Overall	*Carex vesicaria* L.	0.17	0.12	0.19	0.165 ≤ p ≤ 0.17**
Overall	*Cynodon dactylon* (L.) Pers.	0.07	0.09	-0.13	0.068 ≤ p ≤ 0.072*
Overall	*Flemingia lineata* (L.) Aiton	0.01	0.01	0.33	0.011 ≤ p ≤ 0.013**
Overall	*Hemarthria compressa* (L.f.) R.Br.	0.18	0.17	0.03	0.176 ≤ p ≤ 0.181
Overall	*Litsea salicifolia* (Roxburgh ex Nees) Hook. f.	0.01	0.01	0.15	0.008 ≤ p ≤ 0.009
Overall	*Merremia umbellata* (L.) Hallier f.		0.02	-1.00	
Overall	*Mikania micrantha* Kunth	0.01	0.01	0.02	0.006 ≤ p ≤ 0.007*
Overall	*Mimosa* spp.		0.01	-1.00	
Overall	*Paspalum conjugatum* P.J.Bergius	0.01	0.01	0.18	0.013 ≤ p ≤ 0.015**
Overall	*Saccharum* spp.	0.48	0.51	-0.05	0.478 ≤ p ≤ 0.485*
Dry	*Alpinia nigra* (Gaertn.) Burtt	0.07	0.03	0.36	0.064 ≤ p ≤ 0.067**
Dry	*Carex vesicaria* L.	0.16	0.11	0.22	0.155 ≤ p ≤ 0.16**
Dry	*Cynodon dactylon* (L.) Pers.	0.08	0.10	-0.15	0.074 ≤ p ≤ 0.078*

Season	Plant species	U	A	JI	BI (90% CI)
Dry	*Flemingia lineata* (L.) Aiton	0.01	0.01	0.22	0.012 ≤ p ≤ 0.014*
Dry	*Hemarthria compressa* (L.f.) R.Br.	0.18	0.17	0.03	0.18 ≤ p ≤ 0.186*
Dry	*Litsea salicifolia* (Roxburgh ex Nees) Hook. f.	0.01	0.01	0.14	0.009 ≤ p ≤ 0.01*
Dry	*Merremia umbellata* (L.) Hallier f.		0.03	-1.00	
Dry	*Mikania micrantha* Kunth	0.01	0.01	-0.19	0.006 ≤ p ≤ 0.008*
Dry	*Mimosa* spp.		0.01	-1.00	
Dry	*Paspalum conjugatum* P.J.Bergius	0.02	0.01	0.19	0.015 ≤ p ≤ 0.016**
Dry	*Saccharum* spp.	0.47	0.48	-0.02	0.469 ≤ p ≤ 0.477**
Wet	*Alpinia nigra* (Gaertn.) Burtt	0.05	0.05	0.04	0.05 ≤ p ≤ 0.054**
Wet	*Carex vesicaria* L.	0.21	0.08	0.51	0.203 ≤ p ≤ 0.209**
Wet	*Cynodon dactylon* (L.) Pers.	0.05	0.12	-0.48	0.046 ≤ p ≤ 0.049*
Wet	*Flemingia lineata* (L.) Aiton	0.01	0.01	-0.30	0.007 ≤ p ≤ 0.008**
Wet	*Hemarthria compressa* (L.f.) R.Br.	0.16	0.18	-0.08	0.159 ≤ p ≤ 0.164*
Wet	*Litsea salicifolia* (Roxburgh ex Nees) Hook. f.	0.00	0.01	-0.61	0.002 ≤ p ≤ 0.003*
Wet	*Merremia umbellata* (L.) Hallier f.		0.04	-1.00	
Wet	*Mikania micrantha* Kunth	0.00	0.02	-0.78	0.002 ≤ p ≤ 0.003*
Wet	*Mimosa* spp.		0.01	-1.00	
Wet	*Paspalum conjugatum* P.J.Bergius	0.01	0.01	-0.25	0.007 ≤ p ≤ 0.008*
Wet	*Saccharum* spp.	0.51	0.43	0.16	0.51 ≤ p ≤ 0.517*

U- used proportion, A- available proportion, JI- Jacob's Index, BI- Boneferroni confidence interval on used proportion of forage species (90% confidence coefficient), *- significant differences at 0.10 significance level where forage species used less than its availability, **- significant differences at 0.10 significance level where forage species used more than its availability

References

Ahmed, M. F., Das, A., Prasad Lahkar, B., Nath Sharma, R., & Kumar Vasu, N. (2005). *Inventory of Herpetofauna and Evaluation of their Conservation Status in the Kaziranga National Park with Observations on Impact of Grassland Burning, Assam, India.* Final summary report.

Banerjee, G. (2001). *Habitat Use by the Great Indian Rhinoceros (Rhinoceros Unicornis) and Other Sympatric Large Herbivores in Kaziranga National Park, Assam, India*. Master's dissertation, Wildlife Institute of India, Dehradun.

Barman, R. (2005). A record of Oriental Bay-owl *Phodilus badius* from Kaziranga National Park, Assam, India. *Indian Birds*, *1*(4), 91.

Barua, M., & Sharma, P. (1999). Birds of Kaziranga national park, India. *Forktail*, *15*, 47–60.

Baruah, P. (2007). *Kaziranga National Park, Assam, India.*

Basumatary, R., & Sharma, D. K. (2013). The turtle fauna of Kaziranga National Park, Assam, India with notes on natural history and conservation status. *Herpetology Notes*, *6*, 59–72.

Bhupathy, S., Choudhury, B. C., & Moll, E. O. (1992). *Conservation and management of freshwater turtles and land tortoises of India. Report of the Turtle and Tortoise Conservation Project of Wildlife Institute of India and US Fish and Wildlife services*. Mimeo, 25pp.

Bonal, B. S. (1998). *Status of swamp deer in Kaziranga National Park*. Forest Department, Assam.

Borah, P., Deka, J. R., Ahamad, M., Sharma, R., Badola, R., & Hussain, S. A. (2022). First photographic evidence of Asiatic Black Bear *Ursus thibetanus* in Kaziranga Tiger Reserve, India. *Journal of Threatened Taxa*, *14*(2), 20677–20679.

Boro, A. R., Saikia, P. K., & Saikia, U. (2018). New records of bats (Mammalia: Chiroptera) from Assam, Northeastern India with a distribution list of bat fauna of the state. *Journal of Threatened Taxa*, *10*(5), 11606–11612.

Borthakur, U., & Das, C. (2010). First sighting record of Hooded Pitta *Pitta sordida* from Kaziranga National Park, India. *Indian Birds 5*(5), 158.

Boruah, B., Gogoi, M. J., Payra, A., Das, G. N., Bortamuly, M., & Sharma, R. (2016). Diversity and Habitat Preference of Odonata fauna (Insecta) in Kaziranga- Karbi Hills, Central Assam, Northeast India. *Ambient Science*, *3*(2).

Chanda, S. K. (1994). Anuran (Amphibia) Fauna of Northeast India. *Memoirs of Zoological Survey of India*, *18*.

Choudhury, A. (1987). Railway threat to Kaziranga. *Oryx*, *21*(3), 160-163.

Choudhury, A. (1994). The decline of the wild water buffalo in North-east India. *Oryx*, *28*(1), 70-73.

Choudhury, A. (2001). Primates in Northeast India: An Overview of their Distribution and Conservation Status. In A. K. Gupta (Ed.). *ENVIS Bulletin: Wildlife and Protected Areas, Non-Human Primates of India, Volume 1*(1) (pp. 92-101).

Choudhury, A. U. (1999). Mustelids, Viverrids and Herpestids of Northeastern India. In Hussain, S.A. (Ed.). *ENVIS Bulletin: Wildlife and Protected Areas, Mustelids, Viverrids and Herpestids of India, Volume 2*(2) (pp. 43–47).

Choudhury, A. U. (2004). *Kaziranga- Wildlife in Assam*. Rupa and Co.

Choudhury, A. U. (2011). *Records of Sloth bear and Malayan Sun bear in North east India*. Final report to International Association for Bear Research and Management (IBA), The Rhino Foundation for Nature in NE India, Guwahati, Assam, India. 53pp.

Choudhury. A. (2014). Conservation and status of Threatened Waterbirds in North-East India. In G. V. Gopi & S. A. Hussain (Eds.), *Waterbirds of India, ENVIS Bulletin: Wildlife and Protected Areas*, *Volume 16*. Wildlife Institute of India, Dehradun. 368pp.

Das, A., Ahmed, F., Lahkar, B., & Sharma, P. (2007). A preliminary report of reptilian mortality on road due to vehicular movements near Kaziranga National Park, Assam, India. *Zoos' Print Journal*, *22*(7), 2742–2744.

Gee, E. P. (1967). A note on the occurrence of the Malayan Sun Bear *Helarctos malayanus* (Raffles) within Indian limits. *The Journal of the Bombay Natural History Society*, *64*(2), 352-354.

Gogoi, M. J. (2013). Notes on some skipper butterflies (Lepidoptera: Hesperiidae) from Panbari Forest and its adjoining areas, Kaziranga-Karbi Anglong, upper Assam, India. *Journal of Threatened Taxa*, *5*(13), 4759–4768.

Gogoi, M. J. (2015). Observations on lycaenid butterflies from Panbari Reserve Forest and adjoining areas, Kaziranga, Assam, Northeastern India. *Journal of Threatened Taxa*, *7*(15), 8259–8271.

Kullander, S. O., Rahman, M. M., Norén, M., & Mollah, A. R. (2018). *Laubuka tenella*, a new species of cyprinid fish from Southeastern Bangladesh and Southwestern Myanmar (*Teleostei, Cyprinidae, Danioninae*). *ZooKeys*, 742, 105–126.

Laskar, B. A., Kumar, V., Kundu, S., Darshan, A., Tyagi, K., & Chandra, K. (2018). DNA barcoding of fishes from River Diphlu within Kaziranga National Park in Northeast India. *Mitochondrial DNA Part A: DNA Mapping, Sequencing, and Analysis*, *30*(1), 126–134.

Menon, A. G. K. (1999). *Check list - Fresh water fishes of India*. Records of the Zoological Survey of India. 366pp.

Menon, V. (2014). *Indian Mammals: A field guide*. Hachette India.

Molur, S., Srinivasulu, C., Srinivasulu, B., Walker, S., Nameer, P. O., & Ravikumar, L. (2005). *Status of Non-volant Small Mammals: Conservation Assessment and Management Plan Workshop Report*. Zoo Outreach Organisation, Coimbatore. 618pp.

Pathak, B. N. (1978). *Kaziranga National Park-1978 Census Report*. Government of Assam, Department of Forest, 5-46.

Qureshi, Q., Jhala, Y. V., Bankhwal, D. P., Gopal, R., & Bonal, B. S. (2015). North Eastern Hills and Brahmaputra Flood Plains. In Jhala, Y. V., Qureshi, Q., & Gopal, R. (Eds.). *The status of tigers, copredators & prey in India 2014* (pp. 91–108). National Tiger Conservation Authority, New Delhi & Wildlife Institute of India, Dehradun.

Rahmani, A. R., Kasambe, R., Prabhu, S., Khot, R., & Bajaru, S. (2016). *Biodiversity Studies at Kaziranga National Park, Assam, India.* Final Report (March 2015- February 2016). Bombay Natural History Society. 357pp.

Raj Tilak, & Sati, J. P. (1984). On The Occurrence of *Oreichthys cosuatis* (Ham.) in Kaziranga National Park, (Pisces : Cyprinidae). *Bulletin Zoological Survey of India*, *6*(1–3), 279–281.

Saikia, M. K., & Saikia, P. K. (2015). New records of forest birds in North and South Bank Landscapes of Assam, India. *Journal on New Biological Reports*, *4*(2), 169–176.

Senthilkumar, N. (2010). Orthopteroids in Kaziranga National Park, Assam, India. *Journal of Threatened Taxa*, *2*(10), 1227–1231.

Sharma, B., & Sarma, K. (2014). Status Identification and Prediction of Kaziranga-Karbi Anglong Wildlife Corridor of Assam, India, Using Geospatial Technology. *Journal of Landscape Ecology*, *7*(2), 45–58.

Sharma, G. (2018). Studies on the Mammalian Diversity of Kaziranga National Park, Assam, India with their conservation status. *Journal on New Biological Reports*, *7*(1), 15–19.

Singh, H. C., & Varatharajan, R. (2013). Thrips (Insecta: Thysanoptera) fauna of Kaziranga National Park, Assam. *Current Science*, *105*(9), 1219–1223.

Spillett, J. J. (1966). A report on wildlife surveys in north India and southern Nepal: The Kaziranga wildlife sanctuary, Assam. *Journal of the Bombay Natural History Society*, *63*, 494-533.

Spillett, J. J. (1967). The Kaziranga Wild Life Sanctuary, Assam. *The Journal of the Bombay Natural History Society*, *63*(3), 494–528.

Tilak, R., & Sati, J. P. (1984). On the occurrence of *Oreichthys cosuatis* (Ham.) in Kaziranga National Park, (Pisces: Cyprinidae). *Bulletin Zoological Survey of India*, *6*(1–3), 279–281.

Vasu, N. K. (2003). *Management Plan of Kaziranga National Park (2003-2013)*. Forest Department, Assam.

Yadava, M. K. (2014). Detailed report on issues and possible solutions for long term protection of the greater one horned rhinoceros in Kaziranga National Park. *Government of Assam, Kaziranga National Park.*

PLATES

Plate 1. Glimpses of (a) Grassland, (b) *beel*, (c) Woodland, (d) livestock grazing with swamp deer, (e) control burning and (f) NH-37 and local community in KNP.

a)

b)

c)

d)

e)

f)

Plate 2. Glimpses of a) rhino, b) rhino dung, c) elephant herd, d) elephant feeding in burned tall grassland, e) buffalo mating, f) buffalo dung, g) swamp deer, h) swamp deer pellet, i) hog deer feeding in short grassland, j) hog deer pellets, and k) sambar.

a)

b)

c)

d)

e)

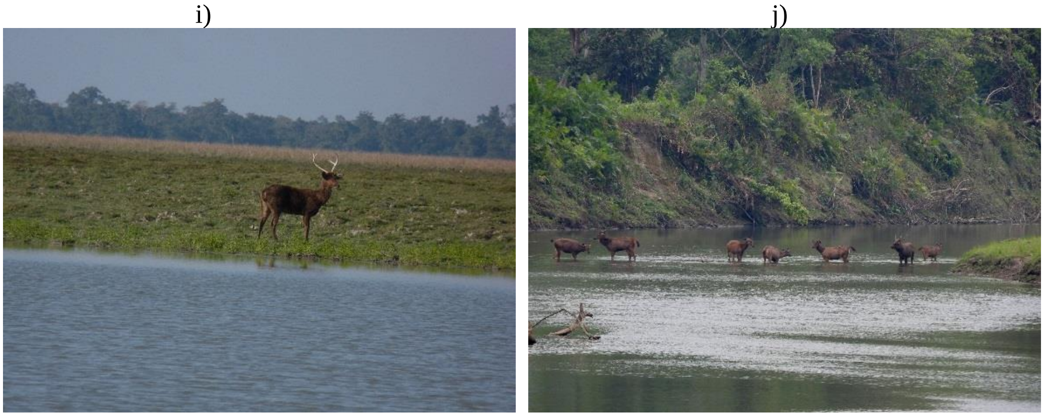
f)

g)

h)

i)

j)



k)

Plate 3. Glimpses of a) reference plant collection, b) faecal sample collection, c) sun drying samples, d) sample washing, e) air drying of washed samples, f) mixing samples with hydrogen peroxide, g) slide preparation and h) slides examination under a microscope.

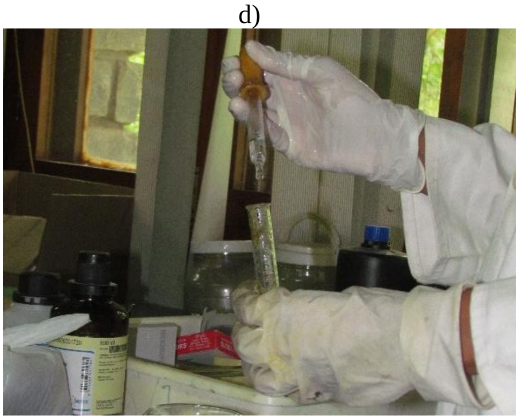
a)

b)

c)

d)

e)

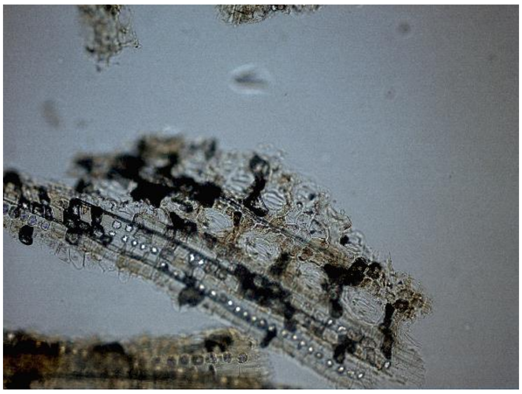


f)

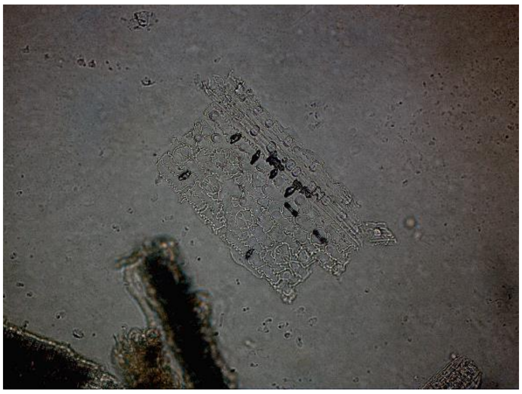
g)

h)

Plate 4. Glimpses of photomicrographs of a) *Alpinia nigra*, b) *Cynodon dactylon,* c) *Echinochloa crus-galli*, d) *Fimbristylis aestivalis*, e) *Imperata cylindrica*, f) *Saccharum* spp., g) *Lippia alba*, and h) *Leucas aspera*.



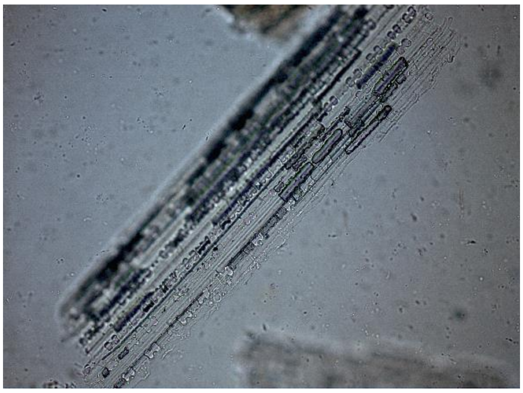
a)



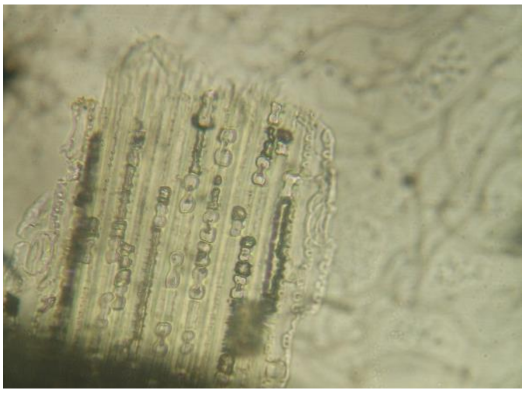
b)

c)

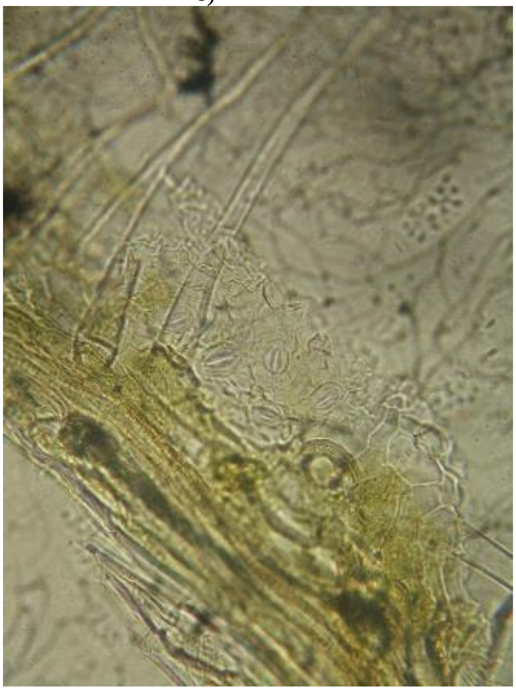
d)



e)



f)



g)

h)

www.nature.com/scientificreports

scientific reports

ISSN: 2045-2322

Check for updates

OPEN

Seasonal pattern of food habits of large herbivores in riverine alluvial grasslands of Brahmaputra floodplains, Assam

Anita Devi, Syed Ainul Hussain✉, Monika Sharma, Govindan Veeraswami Gopi & Ruchi Badola

Jarman–Bell (1974) hypothesized that in the dry savanna of Africa, small-bodied herbivores tend to browse more on forage with high protein and low fibre content. This implies browsing on high nutritive forage by meso-herbivores, and grazing and mixed feeding on coarse forage by mega-herbivores. We tested this hypothesis in the riverine alluvial grasslands of the Kaziranga National Park (KNP), where seasonal flood and fire play an important role in shaping the vegetation structure. We analyzed the feeding habits and quality of major forage species consumed by three mega-herbivores, viz. greater one-horned rhino, Asian elephant, and Asiatic wild buffalo, and three meso-herbivores, viz. swamp deer, hog deer, and sambar. We found that both mega and meso-herbivores were grazers and mixed feeders. Overall, 25 forage plants constituted more than 70% of their diet. Among monocots, family Poaceae with *Saccharum* spp. (contributing > 9% of the diet), and, among dicots, family Rhamnaceae with *Ziziphus jujuba* (contributing > 4% of the diet) fulfilled the dietary needs. In the dry season, the concentration of crude protein, neutral detergent fibre, calcium, sodium, and phosphorous varied significantly between monocots and dicots, whereas only calcium and sodium concentrations varied significantly in the wet season. Dicots were found to be more nutritious throughout the year. Compared to the dry season, the monocots, viz. *Alpinia nigra*, *Carex vesicaria*, *Cynodon dactylon*, *Echinochloa crus-galli*, *Hemarthria compressa*, *Imperata cylindrica*, and *Saccharum* spp., with their significantly high crude protein, were more nutritious during the wet season. Possibly due to the availability of higher quality monocots in the wet season, both mega and meso-herbivores consume it in high proportion. We concluded that the Jarman–Bell principle does not apply to riverine alluvial grasslands as body size did not explain the interspecific dietary patterns of the mega and meso-herbivores. This can be attributed to seasonal floods, habitat and forage availability, predation risk, and management practices such as controlled burning of the grasslands. The ongoing succession and invasion processes, anthropogenic pressures, and lack of grassland conservation policy are expected to affect the availability of the principal forage and suitable habitat of large herbivores in the Brahmaputra floodplains, which necessitates wet grassland-based management interventions for the continued co-existence of large herbivores in such habitats.

Understanding the niche of an animal is crucial for understanding the community dynamics of dependent consumers. Foraging is one of the fundamental elements of a niche[1,2]. In sympatric herbivores, the foraging patterns provide insights into the utilization patterns of the occupied habitat, which is important for making assumptions about the behaviour, physiology, morphology, and population dynamics of the predators, prey, and competitors[3]. In the early 1960s, the ecological succession and separation theory described forage resource partitioning as the reason for the co-existence of herbivores of different body sizes[4–6]. Bell[7] and Jarman[8] explained the co-existence of mega and meso-herbivores as a function of body mass and digestive physiology, whereas Hofmann and Stewart[9] reasoned digestive physiology as the explanation for foraging style. The Jarman–Bell principle emphasized that the quality and quantity of large herbivore diet correlates with their body size; specifically, the diet quality decreases as body size increases. Depending on body size, herbivores consume a large or small amount

Wildlife Institute of India, Chandrabani, Post Box # 18, Dehra Dun, Uttarakhand 248001, India. ✉email: ainul.hussain@gmail.com

of coarse forage to fulfil their body requirement[8,10]. The allometric theory[11] and digestive physiology[12] explained the mechanism behind the Jarman–Bell principle. The allometric theory explained that the length of the digestive tract is directly proportional to the body mass, and consequently, the metabolism rate is inversely proportional to the body mass. Demment and Van Soest[12] provided evidence that the capability to digest coarse forage increases with the increase in gut capacity. Hence, the digestive capability of mega and meso-herbivores plays a crucial role in their dietary selection[13,14]. Thus, depending on both nutritional (crude protein content, mineral content, and digestibility) and anti-nutritional parameters (plant secondary metabolites or fibre), meso-herbivores need to browse on forage with high protein and low fibre content. In contrast, mega-herbivores may feed on forage with low protein and high fibre content[15,16].

The preponderance of the studies that examined the ecology of large assemblages of sympatric herbivores and tested the body mass principle have primarily emerged from Africa and North America[17,18]. The studies conducted to test the Jarman–Bell principle in the African savannas[19–24] and the protected areas of North America[21] primarily covered dry tropical grasslands, forests, or savannas. These studies provided insight into resource segregation, competition, and habitat utilization along the temporal[19,20], and spatial gradients[21–25].

Of the 19 terrestrial mammalian herbivore species with a body mass greater than 100 kg, in South and South-East Asia, 14 are found in India[26]. Though the herbivore species found in India are distinct from those in Africa, the similarities in the diverse range of body sizes, from mega-herbivores like elephant, with a body weight of 3000 to 5400 kg, to meso-herbivores like mouse deer, with a body weight of 2 to 4 kg, provide the opportunity to test the Jarman–Bell principle[6,27,28]. The literature available to understand the science of wild large herbivore foraging ecology at the community level is limited from Asia[29]. Most of the research conducted in India studied up to four wild herbivore species and contributed mostly to their biology and ecology[6,29]. Ahrestani[6] tested the Jarman–Bell principle for chital (*Axis axis*), sambar (*Rusa unicolor*), gaur (*Bos gaurus*), and elephant (*Elephas maximus*) in the dry tropical forests of India, where he concluded that body size does not explain the graze to browse ratio of sambar and chital. Wegge et al.[29] tested the Jarman–Bell principle for rhinoceros (*Rhinoceros unicornis*), swamp deer (*Rucervus duvaucelii*), and hog deer (*Axis porcinus*) in riverine alluvial grasslands of Nepal, where they concluded that the body size does not explain the consumption of higher graminoids by smaller herbivores. There is little understanding of how this principle explains the foraging pattern and resource partitioning among large herbivores along the temporal and spatial gradients in the riverine alluvial grassland ecosystem. Large assemblages of mega and meso-herbivores in the Brahmaputra valley provide an opportunity to examine the applicability of the Jarman–Bell principle in a moist grassland ecosystem, which is subjected to anthropogenic pressure and is vulnerable to climate change.

In the last few decades, climate change and habitat loss have impacted biological systems. It is estimated that since 1970, 58% of animal populations have faced the threat of extinction[30–32]. Climate change poses a serious threat to herbivores directly by influencing rainfall and temperature, and indirectly through the occurrence of extreme climatic events such as fires, floods, and droughts, which may affect the availability and quality of forage and threaten their fitness, survival, migration, and reproductive success[33,34]. Globally, riverine alluvial grasslands in floodplains are threatened, primarily due to fragmentation and degradation of such habitats[35]. In the Brahmaputra valley, remnant riverine alluvial grasslands found mainly in and around protected areas are restricted in their spatial extent thereby, limiting the range of obligate large herbivores[35,36]. The decreasing trend of riverine alluvial grasslands has resulted in low species richness of large herbivore assemblages; consequently, the sample size to validate community ecology theory is often inadequate, which prompts this study[35].

Based on feeding styles, herbivores are generally categorized as grazers (feeding mainly on graminoids or monocots), browsers (feeding mainly on browse or dicots), or mixed feeders (feeding on both monocots and dicots, according to their availability). Any change in the consumption of monocots (grazing) and dicots (browsing) results in changed diet compositions. Experimental studies conducted in the Serengeti-Mara ecosystem in the last 100 years have highlighted the importance of mega and meso-herbivores in converting open grassland to dense woodland and back to grassland[37]. Thus, in succession, both the absence and presence of mega and meso-herbivores plays an important role[38,39]. Browsers and mixed-feeders generally affect the savannas of Africa[40].

Even though the Brahmaputra floodplains in India harbour a large assemblage of mega and meso-herbivores, there is a dearth of studies on their community ecology. The limited information that is available is from Pobitora Wildlife Sanctuary[41,42], Rajiv Gandhi Orang National Park[43], Manas National Park[44], and Kaziranga National Park (KNP)[45–48], and is based on two to three species. Besides, there is little understanding of the habitat dynamics and the impact of seasonal change on the moist alluvial grasslands and their associated fauna. The riverine alluvial grasslands of KNP in the Brahmaputra floodplains are one of the few strongholds of several threatened species including the greater one-horned rhino (*R. unicornis*), Asian elephant (*E. maximus*), Asiatic wild buffalo (*Bubalus arnee*), swamp deer (*R. duvaucelii*), hog deer (*A. porcinus*), and sambar (*R. unicolor*), which necessitates their conservation (Fig. 1). This study was carried out to gain insight into how the body mass principle explains the co-existence of these six mega and meso-herbivores in riverine alluvial grasslands with respect to their diet composition and nutritional quality of principal forage. For the present study, based on the literature on body size and diet composition, the less selective mega-herbivores with very large body sizes (> 1000 kg), viz. rhino, elephant, and buffalo, were categorized as coarse feeders[13,49]. Whereas the more selective meso-herbivores with small to medium body sizes (> 5 kg and < 500 kg), viz. swamp deer, hog deer, and sambar, were categorized as soft feeders[14,50,51].

Based on the information from riverine alluvial grasslands[18,29], we predicted that both mega and meso-herbivores would consume more graze-based diet in the wet season (H_1), and compared to dry season, the principal monocot forage of mega and meso-herbivores would be more nutritious in the wet season (H_2). This study aims to provide an overview of the feeding habits of mega and meso-herbivores with the following research questions: (1) is there any difference in the diet compositions of the mega and meso-herbivores in each season in terms of (a) monocot and dicot, (b) the six categories of growth form, viz. grass, sedge, herb, shrub, climber and

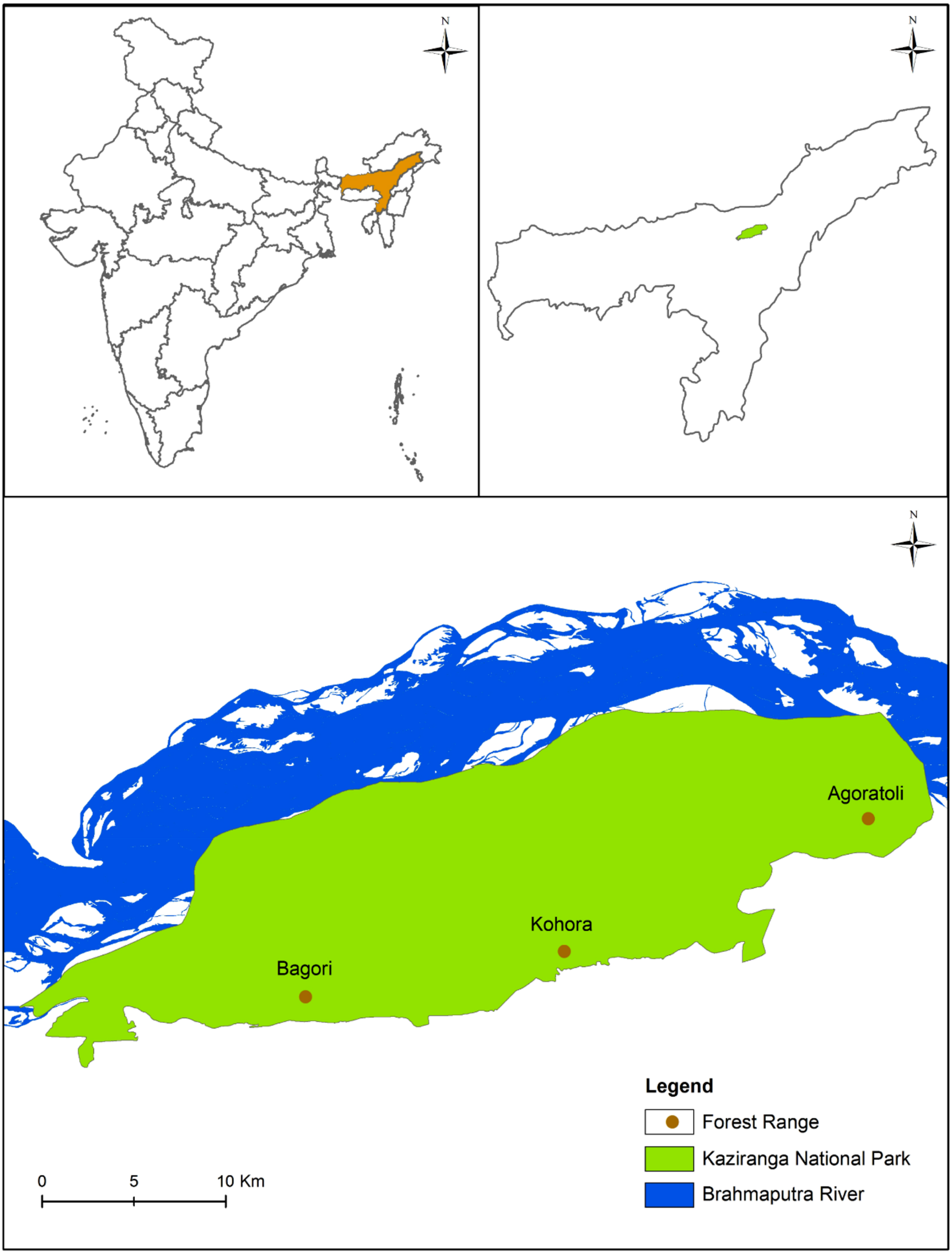


Figure 1. Map showing the location of the riverine alluvial grasslands in Kaziranga National Park, Assam. The map was created using ArcGIS v.10.2.2 software developed by ESRI (https://www.esri.com).

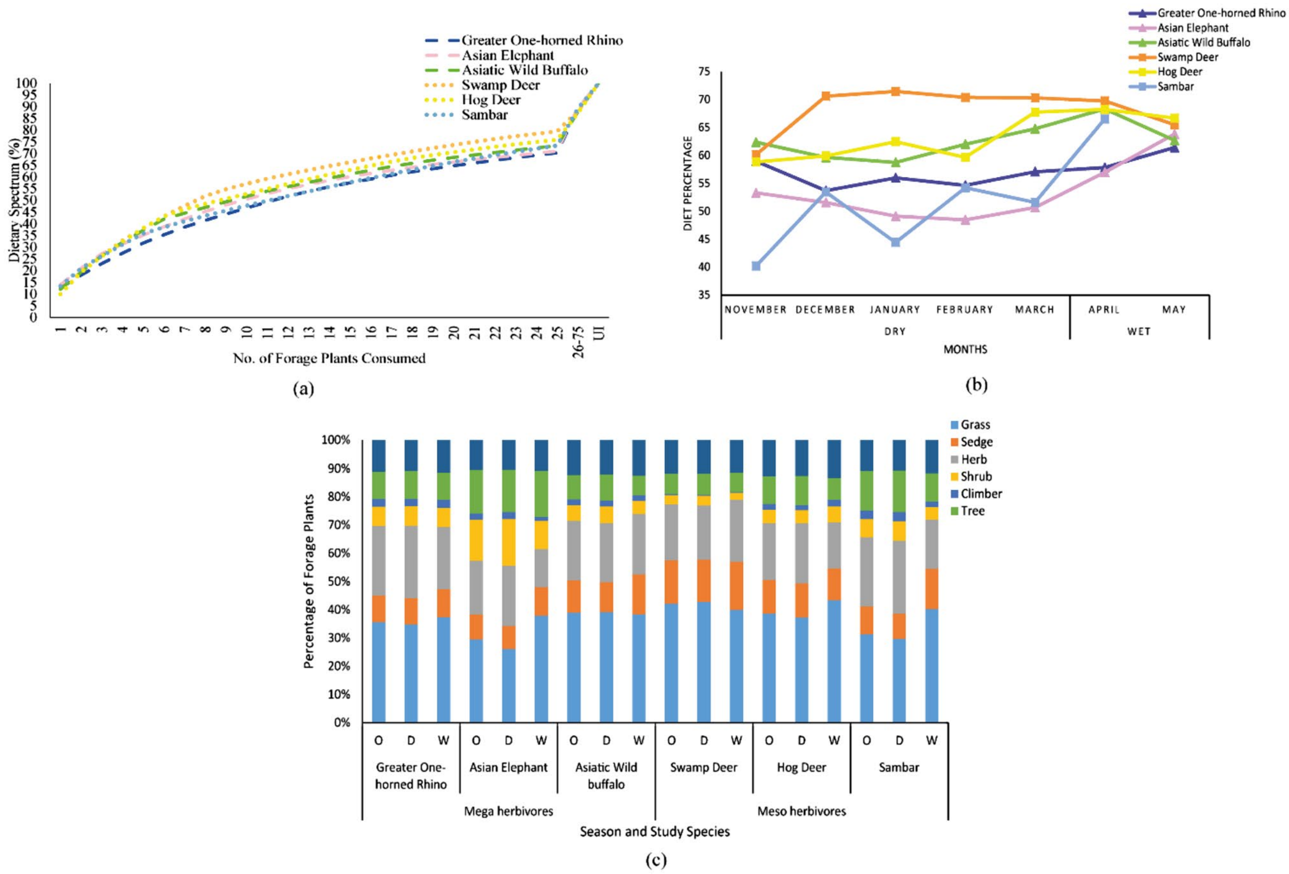


Figure 2. Graph showing (**a**) overall dietary spectrum (%) of major contributing forage plants to the diet, (**b**) monthly consumption of monocots by the six large herbivore species. A high value of the diet percentage suggests a graze-based diet, whereas a low value of the diet percentage suggests a browse-based diet and (**c**) diet composition of mega and meso-herbivores in terms of six growth forms of different forage plants in Kaziranga National Park, Assam.

tree, and (c) the forage plant species contributing to the diets of the mega and meso-herbivores; (2) is there any difference in the seasonal nutrient parameters of major forage plants consumed by mega and meso-herbivores; and (3) which nutrient factors govern the forage utilization by mega and meso-herbivores.

Results

Dietary spectrum. Throughout the year, 25 major forage plants constituted more than 70% of the diet of large herbivores (Fig. 2a), specifically 79.48% of swamp deer's, 75.87% of hog deer's, 73.42% of sambar's, 73.38% of buffalo's, 71.04% of elephant's, and 70.29% of rhino's diet. The 22 principal forage plant species, namely *Saccharum* spp., *Echinochloa crus-galli*, *Cynodon dactylon*, *Ziziphus jujuba*, *Hemarthria compressa*, *Alpinia nigra*, *Carex vesicaria*, *Kyllinga brevifolia*, *Mallotus nudiflorus*, *Lippia alba*, *Fimbristylis aestivalis*, *Amaranthus spinosus*, *Ageratum conyzoides*, *Duchesnea indica*, *Calamus tenuis*, *Oxalis corniculata*, *Imperata cylindrica*, *Acmella uliginosa*, *Amaranthus viridis*, *Dillenia indica*, *Solanum americanum*, and *Setaria pumila* contributed more than 2% each. The highest number of identified principal forage species (n = 22) were recorded for hog deer (n = 14; 61.15%) followed by rhino (n = 13; 53.89%), elephant (n = 12; 55.00%), sambar (n = 12; 51.90%), buffalo (n = 11; 53.97%), and swamp deer (n = 11; 59.29%).

Diet comparison. The mega and meso-herbivores consumed more monocots during the wet season than the dry season (Fig. 2b). There were significant seasonal differences in the consumption of monocots & monocots, dicots & dicots, and monocots & dicots among the six large herbivores. Between the mega and meso-herbivores, there were significant seasonal differences in the consumption of dicots & dicots and monocots & dicots, and no significant seasonal difference in the consumption of monocots & monocots. Among the six growth forms, grasses were dominant in the diet of all the six herbivores (Fig. 2c). There were significant seasonal differences in the consumption of grasses and herbs among the six large herbivores, and no significant differences in the consumption of sedges, shrubs, climbers, and trees. Between the mega and meso-herbivores, there were significant seasonal differences in the consumption of grasses and trees, and no significant seasonal differences in the consumption of sedges, herbs, shrubs, and climbers. A total of 31 families of forage plants were identified in the diet of the mega-herbivores and 29 in the diet of the meso-herbivores. Overall, the Bipartite Ecological

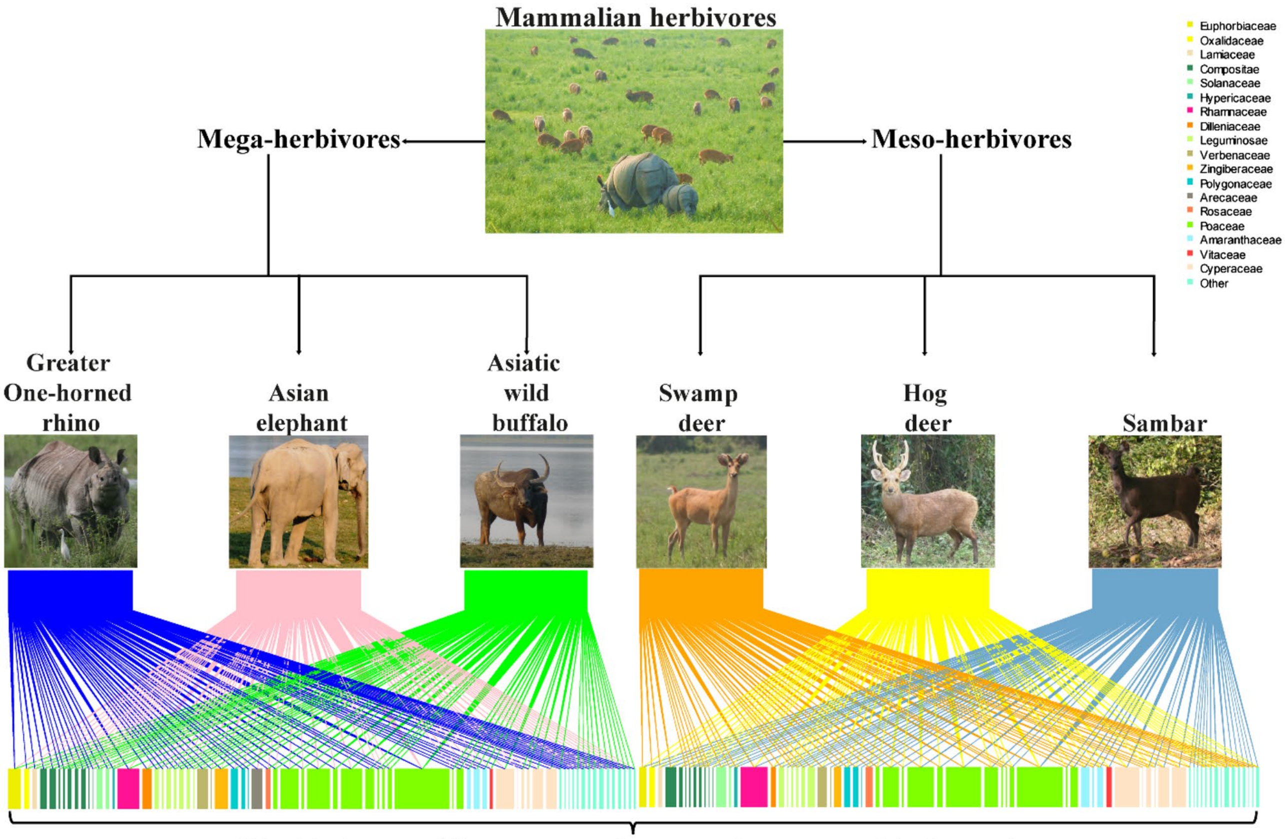


Figure 3. Flow diagram representing the overall bipartite ecological network, which illustrates the diet composition of mega and meso-herbivores. Study species (upper boxes) connected by lines to forage plants (lower boxes) are coloured by family. The width of the lines and lower boxes represent the frequency of occurrence of the forage plants and their respective families in the diet of mega and meso-herbivores in Kaziranga National Park, Assam.

Network (BEN) shows that the members of the family Poaceae contributed the most to the diet of mega and meso-herbivores (Fig. 3). It also shows that the contribution of forage species belonging to the families Poaceae and Cyperaceae, to the diet of both mega and meso-herbivores, increased from dry (34.33 to 57.70%) to wet season (47.27 to 57.06%) (Fig. 4a,b). *C. tenuis* (family Arecaceae) was consumed mostly by the elephant. BEN further revealed that the mean number of shared forage plants in the diet of both mega and meso-herbivores in the dry and wet seasons were 57.6 and 51, respectively. The tall grass *Saccharum* spp. constituted a major part of the diet of mega and meso-herbivores during the wet season. A significant seasonal difference in the consumption of *Saccharum* spp. was observed among the six large herbivores, whereas no significant difference was observed in the consumption of *Saccharum* spp. between the mega and meso-herbivores during different seasons.

Monocots dominated the diet of both mega and meso-herbivores throughout the year (Table 1). Only elephant and sambar consumed a significantly higher proportion of monocots than dicots in the wet season (Table 2). In contrast, there was no significant seasonal difference in the consumption of monocots & dicots by rhino, buffalo, swamp deer, and hog deer. Compared to the dry season, the six herbivores consumed a significantly higher proportion of monocots and a significantly lower proportion of dicots in the wet season.

Grasses dominated the diet of both mega and meso-herbivores throughout the year (Fig. 2c). Between the dry and wet seasons, the six herbivores consumed significantly different proportions of grasses, herbs, climbers, and trees; and only elephant and sambar consumed a significantly different proportion of shrubs. Excluding hog deer, the study species consumed significantly different proportions of sedges (Table 2).

Among the monocots, *Saccharum* spp., *E. crus-galli*, *C. dactylon*, *H. compressa,* and *A. nigra* contributed the most to the rhino diet, while among the dicots, *Z. jujuba*, *M. nudiflorus*, *L. alba*, *A. spinosus*, and *A. conyzoides* contributed the most (Supplementary Table S1). In the elephant diet, *Saccharum* spp., *C. tenuis*, *C. vesicaria*, *E. crus-galli*, and *H. compressa* contributed the most among the monocots, and *Z. jujuba*, *M. nudiflorus*, *D. indica*, *L. alba*, and *A. conyzoides* contributed the most among the dicots (Supplementary Table S2). In the buffalo diet, *Saccharum* spp., *H. compressa*, *E. crus-galli*, *C. vesicaria*, and *C. dactylon* contributed the most among the monocots and, *Z. jujuba*, *O. corniculata*, *L. alba*, *S. americanum*, and *M. nudiflorus* contributed the most among the dicots (Supplementary Table S3). In the diet of swamp deer, among the monocots, *H. compressa*, *Saccharum* spp., *E. crus-galli*, *C. vesicaria*, and *I. cylindrica* contributed the most, and among the dicots, *Z. jujuba*, *A. uliginosa*, *L. alba*, *S. americanum*, and *O. corniculata* contributed the most (Supplementary Table S4). In the hog deer diet, *H. compressa*, *Saccharum* spp., *E. crus-galli*, *C. vesicaria*, and *C. dactylon* contributed the most among the

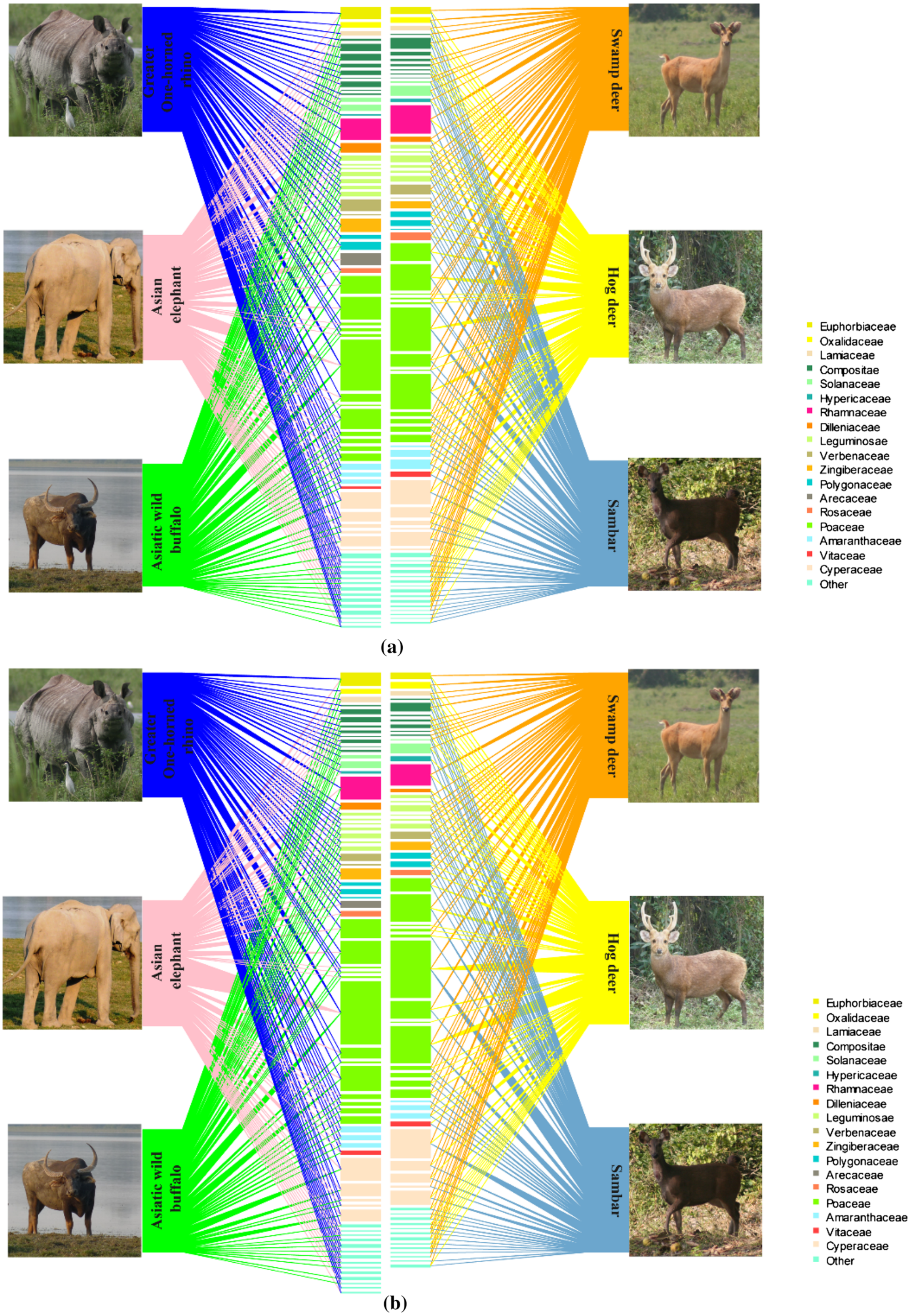


Figure 4. The bipartite ecological network illustrates the diet composition of mega and meso-herbivores. Study species (upper boxes) connected by lines to forage plants (lower boxes) are coloured by family. The width of the lines and lower boxes represent the frequency of occurrence of the forage plants and their respective families in the diet of mega and meso-herbivores in (**a**) dry and (**b**) wet season in Kaziranga National Park, Assam.

Study species	Fragments									Forage plants				
	I	I %	UI	UI %	Total	M	M%	D	D%	I	I %	UI	UI %	Total
Greater One-horned Rhino	7519	88.99	930	11.01	8449	4827	57.13	3622	42.87	69	88.99	55	11.01	124
Asian Elephant	7184	89.55	838	10.45	8022	4295	53.54	3727	46.46	67	89.55	38	10.45	105
Asiatic Wild Buffalo	6403	87.77	892	12.23	7295	4567	62.60	2728	37.40	62	87.77	34	12.23	96
Swamp Deer	6595	88.23	880	11.77	7475	5111	68.37	2364	31.63	59	88.23	31	11.77	90
Hog Deer	6419	87.23	940	12.77	7359	4628	62.89	2731	37.11	59	87.23	32	12.77	91
Sambar	6277	89.19	761	10.81	7038	3622	51.46	3416	48.54	63	89.19	29	10.81	92

Table 1. Identified and unidentified fragments and forage plants recorded in the diet of mega and meso-herbivores throughout the year during 2013–15 in Kaziranga National Park, Assam. *I* identified, *UI* unidentified, *M* monocots, *D* Dicots.

Forage category	Six large herbivores			Mega and meso-herbivore			Greater one-horned rhino			Asian elephant			Asiatic wild buffalo			Swamp deer			Hog deer			Sambar		
	χ^2	df	p	χ^2	df	p	χ^2	df	p	χ^2	df	p	χ^2	df	p	χ^2	df	p	χ^2	df	p	χ^2	df	p
M & M	11.29	5	0.05	3.19	1	0.07	65.60	1	0.00	46.59	1	0.00	71.36	1	0.00	88.78	1	0.00	68.19	1	0.00	99.11	1	0.00
D & D	31.21	5	0.00	4.69	1	0.03	63.48	1	0.00	86.58	1	0.00	57.97	1	0.00	39.80	1	0.00	62.11	1	0.00	173.97	1	0.00
M & D	56.63	5	0.00	6.59	1	0.01	0.64	1	0.43	5.63	1	0.02	1.03	1	0.31	0.08	1	0.78	2.00	1	0.16	11.06	1	0.00
Grass	14.81	5	0.01	4.18	1	0.04	37.64	1	0.00	14.29	1	0.00	47.88	1	0.00	68.79	1	0.00	35.64	1	0.00	62.04	1	0.00
Herb	25.28	5	0.00	0.23	1	0.63	10.88	1	0.00	7.23	1	0.01	8.45	1	0.00	16.64	1	0.00	19.05	1	0.00	16.29	1	0.00
Tree	10.45	5	0.06	4.56	1	0.03	47.02	1	0.00	50.29	1	0.00	24.97	1	0.00	13.26	1	0.00	39.68	1	0.00	85.92	1	0.00
Sedge	2.44	5	0.79	1.34	1	0.25	8.33	1	0.00	37.69	1	0.00	15.51	1	0.00	4.55	1	0.03	3.46	1	0.06	21.56	1	0.00
Shrub	6.79	5	2.37	0.06	1	0.81	3.56	1	0.06	9.00	1	0.00	3.27	1	0.07	2.78	1	0.10	1.14	1	0.29	10.89	1	0.00
Climber	4.30	5	0.51	0.22	1	0.64	10.24	1	0.00	15.71	1	0.00	15.00	1	0.00	9.00	1	0.00	20.43	1	0.00	47.82	1	0.00
Saccharum spp[a]	16.62	5	0.01	1.61	1	0.21	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Table 2. Chi-square test for food choices of the mega and meso-herbivores between dry and wet season (M-monocots; D-dicots) during 2013–15 in Kaziranga National Park, Assam. [a]Principal forage of mega and meso-herbivores.

monocots, and *Z. jujuba*, *A. viridis*, *D. indica*, *S. americanum*, and *L. alba* contributed the most among the dicots (Supplementary Table S5). In the diet of sambar, among the monocots, *Saccharum* spp., *E. crus-galli*, *H. compressa*, *C. vesicaria*, and *I. cylindrica* contributed the most, and among the dicots, *Z. jujuba*, *A. uliginosa*, *S. americanum*, *D. indica*, and *M. nudiflorus* contributed the most (Supplementary Table S6).

Forage quality. Throughout the year, the highest crude protein (CP) was recorded for *E. crus-galli* (12.16%) and lowest for *Saccharum* spp. (6.02%), among the monocots. In the dry season, the highest CP was recorded for *C. tenuis* (10.87%) and lowest for *Saccharum* spp. (4.75%), whereas in the wet season, the highest CP was recorded for *E. crus-galli* (16.47%) and lowest for *A. nigra* (9.11%) (Supplementary Tables S7–S9). Compared to the dry season, the monocots showed a higher mean concentration of CP, calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), and phosphorous (P), and a lower mean concentration of ash content (AC), acid detergent lignin (ADL), acid detergent fibre (ADF), and neutral detergent fibre (NDF) in the wet season. There were significant differences in AC, CP, ADL, Na, K, and P content (Mann–Whitney, $p < 0.05$) in monocots between the dry and wet seasons (Supplementary Table S10). The most consumed monocot species in mega and meso-herbivores diet, viz. *Saccharum* spp., showed significant differences in AC, CP, ADL, and K concentrations (Mann–Whitney, $p < 0.05$), between the dry and wet seasons. The monocots, *A. nigra*, *C. vesicaria*, *C. dactylon*, *E. crus-galli*, *H. compressa*, and *I. cylindrica* showed a significant difference in CP concentration (Mann–Whitney, $p < 0.05$), between the dry and wet seasons. Among the dicots, throughout the year and in both the dry and wet seasons, the highest CP concentration was recorded for *A. viridis* and lowest for *D. indica*. Compared to the dry season, dicots showed a higher mean concentration of ADF, NDF, Mg, Na, K, and P, and a lower mean concentration of CP, ADL, and Ca in the wet season. However, there was no significant difference in the nutrient concentration of dicots between dry and wet seasons. In dicots, the most consumed forage species in the diet of mega and meso-herbivores, viz. *Z. jujuba*, showed a significant difference only in ADL concentration (Mann–Whitney, $p < 0.05$), between the dry and wet seasons.

Throughout the year and in both the dry and wet seasons, dicots with their high CP and mineral concentrations were more nutritious than monocots. While there were significant changes in the nutritional quality parameters of monocots from the dry to wet season, no significant seasonal changes in the nutritional quality of dicots were recorded (Supplementary Table S10). Throughout the year, there were significant differences in CP, ADL,

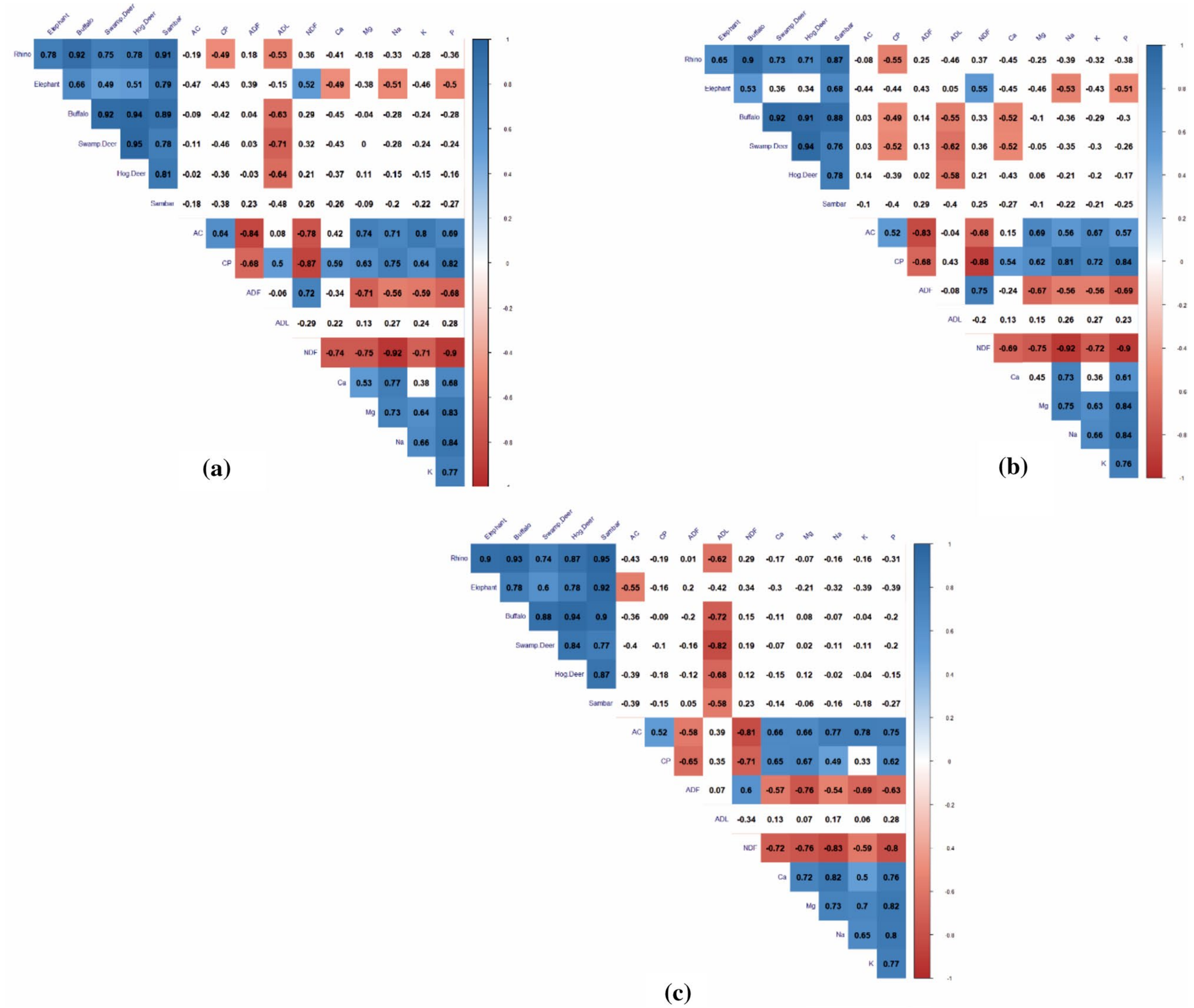


Figure 5. Correlogram showing the relationship between nutrient parameters and the major forage consumed by mega and meso-herbivores in (**a**) overall, (**b**) dry and (**c**) wet season. The values within white boxes represent the insignificant correlation ($p > 0.05$) whereas the values within red (negative correlation) and blue (positive correlation) boxes represent the significant correlation ($p < 0.05$).

NDF, Ca, Na, and P concentrations (Mann–Whitney, $p < 0.05$), between monocots and dicots. In the dry season, there were significant differences in CP, NDF, Ca, Na, and P concentrations (Mann–Whitney, $p < 0.05$) between monocots and dicots. In the wet season, between monocots and dicots, there were significant differences in Ca, and Na concentrations (Mann–Whitney, $p < 0.05$). The concentrations of ADL, Na, K, and P (Mann–Whitney, $p < 0.05$) in monocots and dicots differed significantly between the dry and wet seasons.

The top model selection for forage consumption revealed that throughout the year and in the dry season, ADL concentration influenced forage use by mega and meso-herbivores, excluding elephant, whose forage use was influenced by NDF concentration (Supplementary Table S11). In the wet season, AC and ADL concentrations influenced the major forage use. The correlogram revealed that throughout the year, rhino significantly consumed forage with low CP and ADL concentrations; elephant significantly consumed forage rich in NDF and low in Ca, Na, and P; and buffalo, swamp deer, and hog deer significantly consumed forage with low ADL content (Fig. 5a). In the dry season, rhino significantly consumed forage with low CP; elephant significantly consumed forage rich in NDF and low in Na and P; buffalo and swamp deer significantly consumed forage with low CP, ADL, and Ca; and hog deer significantly consumed forage with low ADL concentration (Fig. 5b). In the wet season, rhino, buffalo, swamp deer, hog deer, and sambar significantly consumed forage with low ADL concentration, whereas elephant significantly consumed forage with low AC (Fig. 5c).

Discussion

With their large body size, the rhino and elephant require almost 150 kg and 240 kg of fodder, respectively, every day, and thus spend most of their time foraging[41,49,52]. Mega and meso-herbivores consumed more monocots in the wet season than in the dry season, although the swamp deer consistently consumed more monocots than other herbivores species. An increase in graze from the dry to the wet season has been recorded in different studies, which also reported 22 to 283 forage plants in the diet of rhino[18,44], 46 to 112 forage plants in the diet of elephant[18,53,54], 183 forage plants in the diet of buffalo[48], 13 to 42 forage plants in the diet of swamp deer[2,29,50], and 15 to 20 forage plants in the diet of hog deer[29,55]. The diet of sambar is flexible and changes according to the availability of forage[56,57] and studies have recorded 15 to 180 forage plants in the diet of sambar[50,58].

In the present study, 124 forage plants in the diet of rhino were recorded of which 69 were identified up to species level and 55 were identified as monocots and dicots. For the elephant, 105 forage plants were recorded in the diet, of which 67 were identified up to species and 38 only as monocots and dicots. For buffalo, 96 forage plants were recorded in diet, of which 62 were identified up to species and 34 only as monocots and dicots. For swamp deer, 90 forage plants were recorded in the diet, of which 59 were identified up to species and 31 only as monocots and dicots. For hog deer, 91 forage plants were recorded in the diet, of which 59 were identified up to species and 32 were only identified as monocots and dicots. For sambar, 92 forage plants were recorded in the diet, of which 63 were identified up to species and remaining 29 only as monocots and dicots. BEN shows that in both the dry and wet seasons, graminoids constituted 50% or more of the diet of both mega and meso-herbivores and Poaceae and Cyperaceae as the most recorded families. In the family Poaceae, the tall grass *Saccharum* spp. was dominant, which might be because of its availability throughout the year. The diet of swamp deer and hog deer had more of the short grass species *H. compressa* in the dry season and more of the tall grass species *Saccharum* spp. in the wet season. *C. tenuis* (family Arecaceae) was mostly consumed by elephant, the possible reason for this could be their ability to exploit resources that are not accessible to other species studied in the area because of its trunk.

We could not detect the presence of important fodder species such as *Mallotus philippinensis* in the diet of any of our study species, even though they were common in the study area and the evidence of browsing on it was observed. In other studies, in similar habitats, its presence could not be detected in the diet of elephant, swamp deer, and hog deer through faecal analysis (e.g., Pradhan et al.[18], Wegge et al.[29], and Steinheim et al.[59]). This is an inherent problem in the feeding habit study using micro-histological methods. Further, we failed to detect the presence of *Bombax ceiba*, another common species in the area, though elephants eat its bark. In several other studies (e.g., Brahmachary et al.[45], and Patar[47]), it was concluded that the large herbivores do not eat *B. ceiba* leaves but debarking, particularly by elephants, is a common feature. A major proportion of the unidentified dicot forage in the diet thus can be attributed to woodland species like *M. philippinensis*, *Terminalia* spp., *Syzygium fruticosum, Mangifera indica*, and *Ficus* spp. These are the reported forage species for rhino and elephant[18,29,41,43,59].

Experimental studies conducted in North America and Europe showed that mega-herbivores meet their physiological needs by feeding more on dominant species. In high productive ecosystems, this favors plant diversity, whereas in low productive ecosystems, this negatively affects plant diversity[60]. In contrast, selective feeding by meso-herbivores negatively affects plant diversity[61]. Therefore, feeding choices, population, and physiological demand of mega and meso-herbivores can alter the vegetation composition[62]. The present study revealed that throughout the year, among dicot plants, *Z. jujuba* was mostly consumed by both mega and meso-herbivores. Similarly, among monocot plants, *Saccharum* spp. was largely consumed by rhino, elephant, buffalo, and sambar throughout the year. Whereas, *H. compressa* was largely consumed by swamp deer, and hog deer. This suggests the dependence of mega and meso-herbivores on these particular dicots and monocots. The nutrient analysis of major forage also revealed that the major forage species consumed throughout the year by mega and meso-herbivores were more nutritious in the wet season. In the future, any changes in the availability, accessibility, and nutrient content of the major forage plants might affect the population of these mega and meso-herbivores. Therefore, further experimental studies explaining the factors responsible for feeding choices as well as the impact of mega and meso-herbivores on plant vegetation are required, to understand the community vegetation dynamics in KNP.

Conclusions and conservation implications

The information on the diet composition provides insight into the feeding habits of the mega and meso-herbivores in the wet grasslands of the Brahmaputra floodplains. The findings of this study support the hypothesis that both mega and meso-herbivores consumed a more graze-based diet in the wet season than in the dry season (H_1). The mega and meso-herbivores grazed more during the wet season, although browse also formed a significant portion of the diet; indicating that both mega and meso-herbivores were grazers and mixed feeders. As monocots were found to be dominant in the forage of rhino, buffalo, swamp deer, and hog deer throughout the year, these species may be more involved in grazing during both the dry and wet seasons. The herbivores, while foraging on nutrient-rich forage, might consume chemically defended forage, resulting in the consumption of toxic plant secondary metabolites (tannins and polyphenols). The detoxification of the secondary metabolites requires more energy. Therefore, to avoid toxic plant secondary metabolites, herbivores might feed on low nutrient quality forage[63]. The shifting of elephant and sambar in the wet season from browsing to grazing indicates their flexibility in utilization of the available forage. The availability of green and nutrient-rich forage is due to the higher moisture regime and controlled burning of wet grasslands. This could be the reason why mega and meso-herbivores feed more on monocots in the wet season[18]. The present study also supports the hypothesis of more nutritious principal monocot forage in the wet season (H_2). Compared to other herbivores, the diet of rhino, elephant, and sambar consisted more of browse. This contradicts the Jarman–Bell principle, according to which large-bodied herbivores feed mostly on less nutritious graminoids. The seasonal changes in forage availability, mouth size, gut physiology, and predation risk might be responsible for the differences in the forage consumption among mega and meso-herbivores as observed in other studies (e.g., Pradhan et al.[18], Wegge et al.[29], Steinheim et al.[59]).

The study suggests that tall and short grasses play a crucial role in meeting the dietary requirements of both mega and meso-herbivores and the importance of riverine alluvial floodplain grasslands in conserving the mega and meso-herbivores. In KNP, the ongoing processes of succession and invasion threaten the grasslands, which in the future might affect the availability of the principal forage plants consumed by mega and meso-herbivores. Thus, grassland-based effective management interventions for conserving the crucial habitat of mega and meso-herbivores are suggested. In the climate crisis and habitat degradation era, the present study will help Park managers to formulate effective conservation strategies for conserving mega and meso-herbivores.

Materials and methods

Study area. KNP, in the north-eastern Indian state of Assam, is situated in the floodplains of the Brahmaputra River, which runs along the northern boundary of the Park; and the Karbi Anglong Hills form the southern boundary. KNP, with an area of 429.93 km^2, lies between latitudes 26° 34′ N and 26° 46′ N and longitudes 93° 08′ E and 93° 36′ E (Fig. 1). An effort to conserve the rhino started with the declaration of Kaziranga as a Reserve Forest in 1908. It was later declared a Wildlife Sanctuary in 1950 and upgraded to a National Park in 1974. Subsequently, it was declared a UNESCO World Heritage Site in 1985 and a Tiger Reserve in 2007[64]. After more than 100 years of conservation efforts, the population of the wildlife in the area has increased[64]. KNP, with its flat terrain and rich alluvial soil, is characterized by numerous permanent water bodies, locally known as *beels*. The climate is of the typical subtropical monsoon type. The total annual precipitation in the study area varies from 1592.8 to 2247.8 mm (2011–2015, Assam Forest Department) with a mean annual precipitation at 1802.7 ± 118.5 mm.

Floods from the Brahmaputra River play a crucial role in the maintenance of the wet grassland ecosystem in KNP, which largely constitutes of tall grasses, short grasses, wetlands, and semi-evergreen forests[65], and supports one of the world's largest population of rhino and buffalo, and significant populations of the Eastern swamp deer and elephant[64]. KNP is home to eight mega and meso-herbivores, viz. *R. unicornis*, *E. maximus*, *B. arnee*, *Bos gaurus*, *R. duvaucelii*, *A. porcinus*, *R. unicolor,* and *Muntiacus muntjak*[66].

Food habit study. The micro-histological analysis was used to study the feeding habits of the mega and meso-herbivores[2,29,55,67]. This technique involves the preparation of reference slides from the plant material (leaf, stems, flower, and fruit) and comparing it with the slides prepared from the known faecal samples of mega and meso-herbivores[29,68]. The microscopic identification of forage plant fragments was carried out using the keys from Satkopan[69] and Johnson et al.[70]. For reference samples, 75 potential forage plants were collected from the field, based on literature review and direct field observations[2,29,67] (Supplementary Table S12). The taxonomic identification of reference plant materials was based on flora of the Kaziranga and Manas National Parks[71–73]. The samples were oven-dried at 60 °C for 48 h[74], stored in labelled paper bags, and brought to the headquarter for laboratory analysis. The reference samples were processed using the micro-histological technique[29] in the laboratory (Fig. 6a).

Seventy-five potential forage plants belonging to 31 families were collected. Twenty-eight percent (n = 21) of these were monocots, and 72% (n = 54) were dicots. Among the six growth forms, 17.33% (n = 13) were grasses, 8% (n = 6) were sedges, 6.66% (n = 5) were climbers, 44% (n = 33) were herbs, 17.33% (n = 13) were shrubs, and 6.66% (n = 5) were trees. Of these 75 forage plants, 42.67% (n = 32) were collected from short grasslands, 29.33% (n = 22) from tall grasslands and 28% (n = 21) from woodlands (Supplementary Table S12).

Fresh dung samples of mega-herbivores, viz. rhino, elephant and buffalo, and pellets of the meso-herbivores, viz. swamp deer, hog deer, and sambar, were collected each month from November 2013 to April 2015 (excluding the flood period from June till October, during which Park remains closed and sample collection was not possible)[64,75]. For the elephant, buffalo, swamp deer, hog deer, and sambar, the faecal samples were collected opportunistically, whereas, for rhino, the faecal samples were collected from latrine sites[76]. These faecal samples were collected from random locations in the short and tall grasslands and woodlands within three forest ranges of KNP, namely Kohora (central), Agoratoli (eastern), and Bagori (western) (Supplementary Table S13). Overall, 1975 faecal samples were collected for both mega and meso-herbivores, of which 1500 samples were collected in the dry season (from November to March) and 475 samples in the wet season (April to May) (Supplementary Table S14). For mega-herbivores, a fresh dung sample, weighing about 400 gm was collected[29,59]. Based on the study by Jachmann and Bell[77], which showed a positive linear relationship between elephant size, and weight and circumference of boli (individual faeces), we used boli as a guideline for elephant dung sample collection to ensure representation from varied body size individuals[59]. The faecal samples collected from randomly selected habitats within similar locations and ranges were used to make composite samples. For mega-herbivores, five dung samples collected from the same location on the same date were selected randomly and mixed thoroughly to make one composite sample. From this composite sample, 25 g of grounded dung sample was used for micro-histological analysis following Wegge et al.[29]. Similarly, five faecal pellets of the meso-herbivores from each five randomly collected pellet samples were pooled together to make one composite sample. The composite samples were processed using the micro-histological technique following Wegge et al.[29]

Five slides were prepared from each composite sample. Seventy composite samples and 350 slides each were prepared (no. of observations, n = 3500) for rhino and elephant. Sixty-five composite samples and 325 slides each were prepared for buffalo, swamp deer, and hog deer (n = 3250), and 60 composite samples and 300 slides were prepared for sambar (n = 3000). Observations with at least two identifiable fragments were considered for the detection of forage plant species consumed. Whenever possible, identification up to species level was attempted by comparing each sample with the reference plant samples that included leaf, stems, flower, and fruit. We have taken only leaves, stems, flower, and fruit for the preparation of reference materials, and not the bark or roots. Fragments with identifiable features where identification up to species or genus level was difficult due to damaged fragments were categorized as unidentified monocots (including *Bambusa* spp.), and unidentified dicots (including *M. philippinensis*, *Terminalia* spp., and *S. fruticosum*)[18].

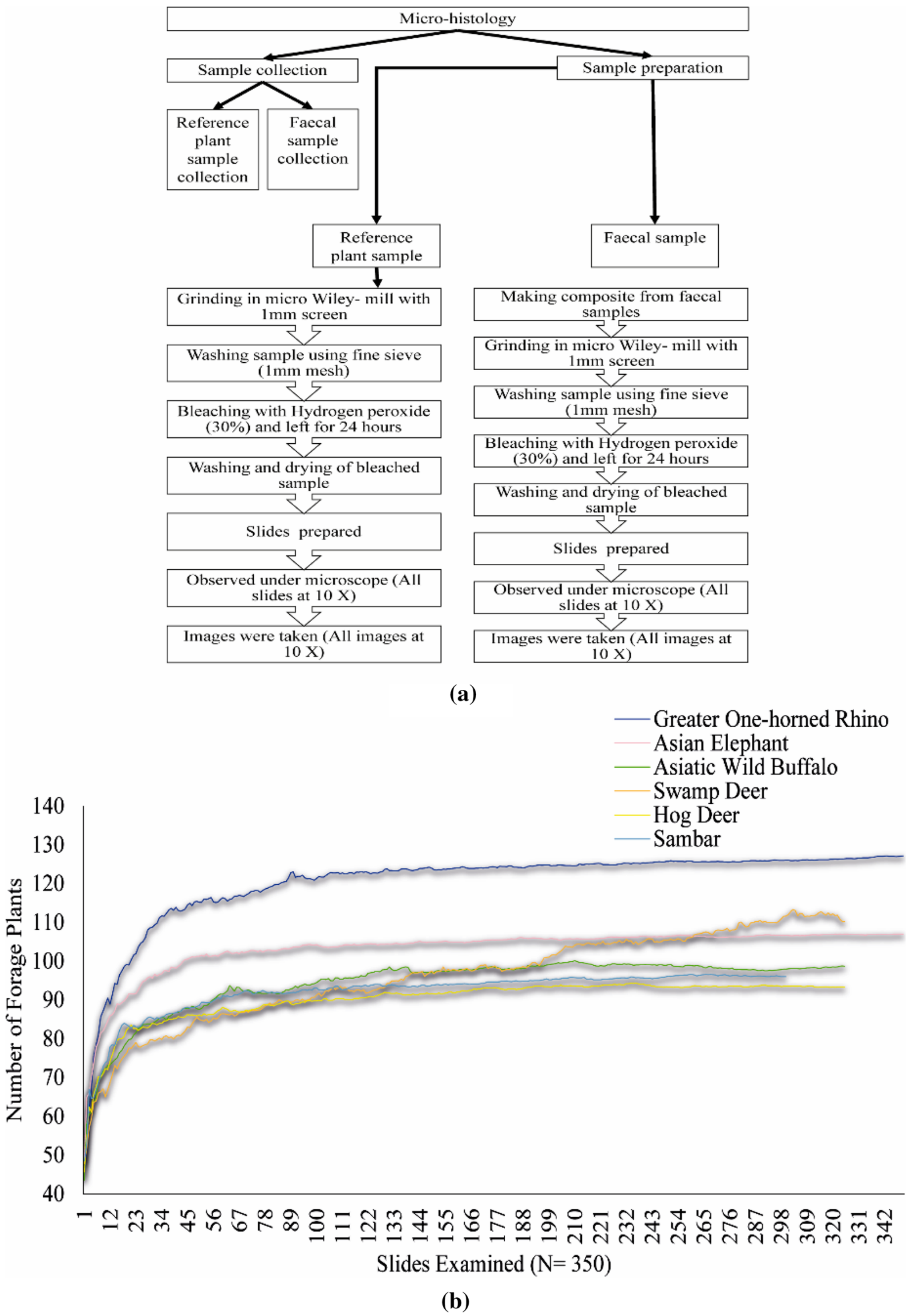


Figure 6. Graph showing (**a**) pathway for micro-histological analysis of plant reference samples and faecal samples and (**b**) overall species accumulation curve for mega and meso-herbivores (Greater one-horned rhino and Asian elephant: N = 350; Asiatic wild buffalo, swamp deer and hog deer: N = 325; sambar: N = 300).

The species accumulation curve was asymptotic at a sample size below the number of slides examined, indicating a sufficient sample size (Fig. 6b). Overall, rhino utilized the maximum number of forage species (n = 124, including both identified and unidentified plants), followed by elephant (n = 105), buffalo (n = 96), sambar (n = 92), hog deer (n = 91), and swamp deer (n = 90) (Table 1).

Forage quality. Based on the results from the micro-histological analysis, the forage plants consumed in the highest proportion by mega and meso-herbivores were collected twice every month from November 2015 to May 2016. These samples were oven-dried at 60 °C for 48 h in the field and finely ground in 1 mm mesh screen of a Cyclotech's micro–Wiley mill and stored in airtight plastic bags for estimation of CP, AC, fibre (NDF, ADF, and ADL), and minerals (Ca, P, Mg, K, and Na). Standard protocols were followed to estimate nutrient content (Supplementary Table S15). For Ca and Mg estimation, AAnalyst 700 Atomic Absorption Spectrometer was used with MERCK Certipur Single-Element Standards of Ca and Mg. Similarly, for P estimation, the SMART Spectro 2 Spectrophotometer was used with standard phosphate solution (KH_2PO_4)[78].

Data analysis. To determine the diet composition of mega and meso-herbivores more precisely, the forage plants identified were categorized further on the basis of (1) graze-to-browse ratio (on monocot and dicot consumption), (2) growth form (grass, sedge, herb, shrub, climber and tree), (3) family, and (4) species. The percentage occurrence of each forage type (graze-to-browse, growth form, family, and species) in the diet of mega and meso-herbivores was determined using the equation of Sparks and Malechek[68] and Tuboi and Hussain[55]:

$$\%\text{ contribution of forage plants} = \frac{\textit{Number of identifiable fragments of each category}}{\textit{Total number of identifiable fragments of all plant species}} \times 100.$$

A species accumulation curve was plotted to determine the sampling effort required to adequately examine the diet composition of mega and meso-herbivores. EstimateS version 9 with a 95% confidence interval was used to produce the species accumulation curve[79]. The number of slides examined and the forage plants identified from the faecal samples of the mega and meso-herbivores were plotted in the species accumulation curve[80]. The dietary spectrum of the mega and meso-herbivores was obtained to visualize the pattern of forage utilization on the basis of the major contributing plants. The chi-square test of association and Fisher's Exact Test were carried out to identify seasonal differences in the forage consumed between the mega and meso-herbivores and among the six herbivores. The tests were performed using SPSS version 22. BEN was used to visualize the forage utilization by mega and meso-herbivores, using R package "bipartite" version 2.11[81]. The forage plants were grouped by family, and only the top 20 abundant families, contributing more than 80% to the diet of mega and meso-herbivores, were highlighted and the rest of the families were grouped under the other category.

The seasonal differences in the nutrient content of major monocot and dicot forage plants were analyzed using a non-parametric Mann–Whitney *U*-test in SPSS version 22. The effect of nutrient factor (predictor) on the use of major forage plants (response) was modelled using a generalized linear model (GLM) and Pearson's correlation analysis. For GLM, R package "MuMin" vers.1.43.17 and for correlogram, R package "Hmisc" vers. 4.4-0 and "corrplot" vers. 0.84 were used[82–84].

Statement for handling plants/plant materials. Experimental research and field studies including collection of plant/plant material for this study, is compliant with the relevant institutional, national, and international guidelines and legislations. The biological samples examined were collected with the permission from the Principal Chief Conservator of Forest (Wildlife) & Chief Wildlife Warden, Government of Assam under section 12 of the Indian Wild Life (Protection) Act, 1972 in O.O No. 868 dated 20th August, 2013. A permission was also obtained from the Director, Kaziranga National Park, Assam in KNP/FG647WII/Research dated 31st October, 2013.

Ethics approval. Experimental research and field studies including collection of plant/plant material for this study, is compliant with the relevant institutional, national, and international guidelines and legislations.

Received: 20 March 2021; Accepted: 13 December 2021
Published online: 10 January 2022

References

1. Krebs, C. J. *Ecological Methodology* 2nd edn. (Addison Welsey Educational Publishers Inc, 1999).
2. Tewari, R. & Rawat, G. S. Studies on the food and feeding habits of Swamp Deer (*Rucervus duvaucelii duvaucelii*) in Jhilmil Jheel conservation reserve, Haridwar, Uttarakhand, India. *ISRN Zool.* **2013**, 1–6. https://doi.org/10.1155/2013/278213 (2013).
3. Brodeur, R. D., Smith, B. E., McBride, R. S., Heintz, R. & Farley, E. New perspectives on the feeding ecology and trophic dynamics of fishes. *Environ. Biol. Fishes.* **100**, 293–297. https://doi.org/10.1007/s10641-017-0594-1 (2017).
4. Vesey-FitzGerald, D. F. Grazing succession among East African game animals. *J. Mammal.* **41**, 161–172. https://doi.org/10.2307/1376351 (1960).
5. Lamprey, H. F. Ecological separation of the large mammal species in the Tarangire game reserve, Tanganyika. *Afr. J. Ecol.* **1**, 63–92. https://doi.org/10.1111/j.1365-2028.1963.tb00179.x (1963).
6. Ahrestani, F. S. *Asian Eden Large Herbivore Ecology in India* (Wageningen University, 2009).
7. Bell, R. H. V. The use of herb layer by grazing ungulates in the Serengeti. In *Animal Populations in Relation to their Food Resources* (eds. Watson, A.) 111–124 (Blackwell Science, 1970).
8. Jarman, P. The social organisation of antelopes in relation to their ecology. *Behaviour* **48**, 215–267. https://doi.org/10.1163/156853974X00345 (1974).
9. Hofmann, R. R. & Stewart, D. R. M. Grazer of browser: A classification based on the stomach structure and feeding habits of East African ruminants. *Mammalia* **36**, 226–240 (1972).
10. Bell, R. H. V. A grazing ecosystem in the Serengeti. *Sci. Am.* **225**, 86–93 (1971).
11. Kleiber, M. *The Fire of Life. An Introduction to Animal Energetics* (Krieger, 1932).

12. Demment, M. W. & Van Soest, P. J. A nutritional explanation for body-size patterns of ruminant and nonruminant herbivores. *Am. Nat.* **125**, 641–672. https://doi.org/10.1086/284369 (1985).
13. Hofmann, R. R. *The Ruminant Stomach: Stomach Structure and Feeding Habits of East African Game Ruminants. East African Monograph in Biology*, vol. 2, 1–364 (E.A. Lit. Bureau, 1973).
14. Ahrestani, F. S., Heitkönig, I. M., Matsubayashi, H. & Prins, H. H. Grazing and browsing by large herbivores in South and Southeast Asia. In *The Ecology of Large Herbivores in South and Southeast Asia*, (eds. Ahrestani, F. S. & Sankaran, M.) 99–120. (Springer, 2016).
15. Geist, V. On the relationship of social evolution and ecology in Ungulates. *Am. Zool.* **14**, 205–220. https://doi.org/10.1093/icb/14.1.205 (1974).
16. Clauss, M., Steuer, P., Müller, D. W. H., Codron, D. & Hummel, J. Herbivory and body size: Allometries of diet quality and gastrointestinal physiology, and implications for herbivore ecology and dinosaur gigantism. *PLoS One* **8**, e68714. https://doi.org/10.1371/journal.pone.0068714 (2013).
17. Ahrestani, F. S., Heitkönig, I. M. & Prins, H. H. Diet and habitat-niche relationships within an assemblage of large herbivores in a seasonal tropical forest. *J. Trop. Ecol.* **28**, 385–394. https://doi.org/10.1017/S0266467412000302 (2012).
18. Pradhan, N. M., Wegge, P., Moe, S. R. & Shrestha, A. K. Feeding ecology of two endangered sympatric mega-herbivores: Asian elephant *Elephas maximus* and greater one-horned rhinoceros *Rhinoceros unicornis* in lowland Nepal. *Wildl. Biol.* **14**, 147–154. https://doi.org/10.2981/0909-6396(2008)14[147:feotes]2.0.co;2 (2008).
19. McNaughton, S. J. & Georgiadis, N. J. Ecology of African grazing and browsing mammals. *Annu. Rev. Ecol. Syst.* **17**, 39–66. https://doi.org/10.1146/annurev.es.17.110186.000351 (1986).
20. Owen-Smith, R. N. *Adaptive Herbivore Ecology: From Resources to Populations in Variable Environments. Adaptive Herbivore Ecology* (Cambridge University Press, 2002). https://doi.org/10.1017/CBO9780511525605.
21. Olff, H., Ritchie, M. E. & Prins, H. H. T. Global environmental controls of diversity in large herbivores. *Nature* **415**, 901–904. https://doi.org/10.1038/415901a (2002).
22. Bailey, D. W. & Provenza, F. D. Mechanisms determining large-herbivore distribution. In *Resource Ecology*, vol. 23 (eds. Prins, H. H. T. & Van Langevelde, F.) 7–28 (Springer, 2008). https://doi.org/10.1007/978-1-4020-6850-8_2.
23. Prins, H. H. T. & Van Langevelde, F. Assembling a diet from different places. In *Resource Ecology*, vol. 23 (eds. Prins, H. H. T. & Van Langevelde, F.) 129–155 (Springer, 2008). https://doi.org/10.1007/978-1-4020-6850-8_12.
24. Fryxell, J. M. *et al.* Landscape scale, heterogeneity, and the viability of Serengeti grazers. *Ecol. Lett.* **8**, 328–335. https://doi.org/10.1111/j.1461-0248.2005.00727.x (2005).
25. Du Toit, J., Rogers, K. & Biggs, H. *The Kruger Experience: Ecology and Management of Savanna Heterogeneity*, vol. 29 (Island Press, 2003).
26. Ripple, W. J. *et al.* Collapse of the world's largest herbivores. *Sci. Adv.* **1**, e1400103. https://doi.org/10.1126/sciadv.1400103 (2015).
27. Menon, V. *Indian Mammals: A Field Guide*. (Hachette India, 2014).
28. Reddy, C. S., Jha, C. S., Diwakar, P. G. & Dadhwal, V. K. Nationwide classification of forest types of India using remote sensing and GIS. *Environ. Monit. Assess.* **187**, 777. https://doi.org/10.1007/s10661-015-4990-8 (2015).
29. Wegge, P., Shrestha, A. K. & Moe, S. R. Dry season diets of sympatric ungulates in lowland Nepal: Competition and facilitation in alluvial tall grasslands. *Ecol. Res.* **21**, 698–706. https://doi.org/10.1007/s11284-006-0177-7 (2006).
30. WWF. *Living Planet: Report 2016. Risk and Resilience in a New Era*. (World Wide Fund for Nature International, 2016).
31. Gebremedhin, B. *et al.* DNA metabarcoding reveals diet overlap between the endangered walia ibex and domestic goats: Implications for conservation. *PLoS One* **11**, e0159133. https://doi.org/10.1371/journal.pone.0159133 (2016).
32. Spooner, F. E., Pearson, R. G. & Freeman, R. Rapid warming is associated with population decline among terrestrial birds and mammals globally. *Glob. Change Biol.* **24**, 4521–4531. https://doi.org/10.1111/gcb.14361 (2018).
33. Texeira, M., Baldi, G. & Paruelo, J. An exploration of direct and indirect drivers of herbivore reproductive performance in arid and semi-arid rangelands by means of structural equation models. *J. Arid Environ.* **81**, 26–34. https://doi.org/10.1016/j.jaridenv.2012.01.017 (2012).
34. Kupika, O. L., Gandiwa, E., Kativu, S. & Nhamo, G. Impacts of climate change and climate variability on wildlife resources in southern Africa: Experience from selected protected areas in Zimbabwe. In *Selected Studies in Biodiversity*, (eds. Şen, B. & Grillo, O.) 1–23 (IntechOpen, 2018). https://doi.org/10.5772/intechopen.70470.
35. Joyce, C. B., Simpson, M. & Casanova, M. Future wet grasslands: Ecological implications of climate change. *Ecosyst. Health Sustain.* **2**, e01240. https://doi.org/10.1002/ehs2.1240 (2016).
36. Vasu, N. K., & Singh, G. Grasslands of Kaziranga National Park: Problems and approaches for management. In *Ecology and Management of Grassland Habitats in India*, vol. 17 (eds. Rawat, G. S., Adhikari, B. S.) 104–113 (Wildlife Institute of India, 2015).
37. Dublin, H. T. Vegetation dynamics in the Serengeti-Mara ecosystem: The role of elephants, fire, and other factors. In *Serengeti II: Dynamics, Management, and Conservation of an Ecosystem*, (eds. Sinclair, A. R. E. & Arcese, P.) 71–90 (University of Chicago Press, 1995).
38. Sinclair, A. R. E. Equilibria in plant–herbivore interactions. In *Serengeti II: Dynamics, Management, and Conservation of an Ecosystem*, (eds. Sinclair, A. R. E. & Arcese, P.) 91–113 (University of Chicago Press, 1995).
39. Augustine, D. J. & McNaughton, S. J. Ungulate effects on the functional species composition of plant communities: Herbivore selectivity and plant tolerance. *J. Wildl. Manag.* **62**, 1165. https://doi.org/10.2307/3801981 (1998).
40. Schmitt, M. H. & Shrader, A. M. Browser population-woody vegetation relationships in Savannas. In *Savanna Woody Plants and Large Herbivores* (eds. Scogings, F. P. & Sankaran, M.) 245–278 (Wiley, 2020). https://doi.org/10.1002/9781119081111.ch9.
41. Konwar, P., Saikia, M. K. & Saikia, P. K. Abundance of food plant species and food habits of *Rhinoceros unicornis* Linn. in Pobitora Wildlife Sanctuary, Assam, India. *J. Threat. Taxa.* **1**, 457–460. https://doi.org/10.11609/jott.o1640.457-60 (2009).
42. Bhatta, R. Ecology and Conservation of Great Indian One-horned Rhino (*Rhinoceros unicornis*) in Pobitora Wildlife Sanctuary, Assam, India (Gauhati University, 2011).
43. Hazarika, B. C. & Saikia, P. K. Food habit and feeding patterns of great indian one-horned rhinoceros (*Rhinoceros unicornis*) in Rajiv Gandhi Orang National Park, Assam, India. *ISRN Zool.* **2012**, 1–11. https://doi.org/10.5402/2012/259695 (2012).
44. Dutta, D. K., Bora, P. J., Mahanta, R., Sharma, A. & Swargowari, A. Seasonal variations in food plant preferences of reintroduced Rhinos *Rhinoceros unicornis* (Mammalia: Perrissodactyla: Rhinocerotidae) in Manas National Park, Assam, India. *J. Threat. Taxa.* **8**, 9525–9536. https://doi.org/10.11609/jott.2486.8.13.9525-9536 (2016).
45. Brahmachary, R. L., Rakshit, B. & Mallik, B. Further attempts to determine the food habits of the Indian Rhinoceros at Kaziranga. *J. Bombay Nat. Hist. Soc.* **71**, 295–299 (1974).
46. Banerjee, G. Habitat Use by the Great Indian Rhinoceros (*Rhinoceros Unicornis*) and Other Sympatric Large Herbivores in Kaziranga National Park, Assam, India (Wildlife Institute of India, 2001).
47. Patar, K. C. *Behavioural Patterns of the One Horned Indian Rhinoceros* (Spectrum Publication Guwahati, 2005).
48. Bawri, M. & Saikia, P. K. Preliminary study on the food plant species of Endangered Asiatic wild water buffalo *Bubalus arnee* Kerr in Kaziranga National Park, Assam India. *NeBIO.* **5**, 49–55 (2014).
49. Sukumar, R. Ecology of the Asian elephant in southern India. I. Movement and habitat utilization patterns. *J. Trop. Ecol.* **5**, 1–18. https://doi.org/10.1017/S0266467400003175 (1989).
50. Schaller, G. B. *The Deer and the Tiger. A Study of Wildlife in India*, (University of Chicago Press, 1967). https://doi.org/10.7208/chicago/9780226736570.001.0001.

51. Dhungel, S. K. & O'Gara, B. W. Ecology of the Hog Deer in Royal Chitwan National Park, Nepal. *Wildl. Monogr.* **119**, 3–40. https://doi.org/10.2307/3830632 (1991).
52. Johnsingh, A. J. T. & Manjrekar, N. Mammals of South Asia, **2** (Universities Press, 2016).
53. Sukumar, R. Ecology of the Asian elephant in southern India. II. Feeding habits and crop raiding patterns. *J. Trop. Ecol.* **6**, 33–53. https://doi.org/10.1017/S0266467400004004 (1990).
54. Baskaran, N., Balasubramanian, M., Swaminathan, S. & Desai, A. A. Feeding ecology of the Asian elephant *Elephas maximus* Linnaeus in the Nilgiri Biosphere Reserve, southern India. *J. Bombay Nat. Hist. Soc.* **107**, 3–13 (2010).
55. Tuboi, C. & Hussain, S. A. Factors affecting forage selection by the endangered Eld's deer and hog deer in the floating meadows of Barak-Chindwin Basin of North-east India. *Mamm. Biol.* **81**, 53–60. https://doi.org/10.1016/j.mambio.2014.10.006 (2016).
56. Kelton, S. D. & Skipworth, J. P. Food of sambar deer (*Cervus unicolor*) in a Manawatu (New Zealand) flax swamp. *N. Z. J. Ecol.* **10**, 149–152 (1987).
57. Semiadi, G., Barry, T. N., Muir, P. D. & Hodgson, J. Dietary preferences of sambar (*Cervus unicolor*) and red deer (*Cervus elaphus*) offered browse, forage legume and grass species. *J. Agric. Sci.* **125**, 99–107. https://doi.org/10.1017/S0021859600074554 (1995).
58. Johnsingh, A. J. T. & Sankar, K. Food plants of chital, sambar and cattle on Mundanthurai Plateau, Tamil Nadu, south India. *Mammalia* **55**, 57–66. https://doi.org/10.1515/mamm.1991.55.1.57 (1991).
59. Steinheim, G., Wegge, P., Fjellstad, J. I., Jnawali, S. R. & Weladji, R. B. Dry season diets and habitat use of sympatric Asian elephants (*Elephas maximus*) and greater one-horned rhinoceros (*Rhinocerus unicornis*) in Nepal. *J. Zool.* **265**, 377–385. https://doi.org/10.1017/S0952836905006448 (2005).
60. Bakker, E. S., Ritchie, M. E., Olff, H., Milchunas, D. G. & Knops, J. M. H. Herbivore impact on grassland plant diversity depends on habitat productivity and herbivore size. *Ecol. Lett.* **9**, 780–788. https://doi.org/10.1111/j.1461-0248.2006.00925.x (2006).
61. Edwards, G. R. & Crawley, M. J. Herbivores, seed banks and seedling recruitment in mesic grassland. *J. Ecol.* **87**, 423–435. https://doi.org/10.1046/j.1365-2745.1999.00363.x (1999).
62. Marquis, R. J. The role of herbivores in terrestrial trophic cascades. In: *Trophic Cascades: Predators, Prey and the Changing Dynamics of Nature*, (eds. Terborgh, J. & Estes, J. A.) 109–123, (Island Press, 2010).
63. Parikh, G. L. *et al.* The influence of plant defensive chemicals, diet composition, and winter severity on the nutritional condition of a free-ranging, generalist herbivore. *Oikos* **126**, 1–8. https://doi.org/10.1111/oik.03359 (2017).
64. Yadava, M. K. *Kaziranga National Park: Detailed Report on Issues and Possible Solutions of Long-Term Protection of the Greater One-horned Rhinoceros in Kaziranga National Park Pursuant to the Order of the Hon'ble Guwahati High Court*. 1–402 (Government of Assam, India, 2014).
65. Champion, H. G. & Seth, S. K. *A Revised Survey of the Forest Types of India* (Govt. of India Press, 1968).
66. Sharma, G. Studies on the mammalian diversity of Kaziranga National Park, Assam, India with their conservation status. *J. New Biol. Rep.* **7**, 15–19 (2018).
67. Shrestha, R., Wegge, P. & Koirala, R. A. Summer diets of wild and domestic ungulates in Nepal Himalaya. *J. Zool.* **266**, 111–119. https://doi.org/10.1017/S0952836905006527 (2005).
68. Sparks, D. R. & Malechek, J. C. Estimating percentage dry weight in diets using a microscopic technique. *J. Range Manag.* **21**, 264–265. https://doi.org/10.2307/3895829 (1968).
69. Satkopan, S. Key to identification of plant remains in animal dropping. *J. Bombay Nat. Hist. Soc.* **69**, 139–150 (1972).
70. Johnson, M. K., Wofford, H. H. & Pearson, H. A. *Microhistological Techniques for Food Habits Analyses* (U.S. Department of Agriculture, 1983).
71. Jain, S. K. & Hajra, P. K. On the botany of Manas Wild Life Sanctuary in Assam. *Bull. Bot. Surv. Ind.* **17**, 75–86 (1975).
72. Hajra, P. K. & Jain, S. K. *Botany of Kaziranga and Manas* (Surya International Publications, 1994).
73. Rahmani, A. R., Kasambe, R., Prabhu, S., Khot, R. & Bajaru, S. *Biodiversity Studies at Kaziranga National Park*. (2016).
74. Vila, A. R., Galende, G. I. & Pastore, H. Feeding ecology of the endangered huemul (*Hippocamelus bisulcus*) in Los Alerces National Park, Argentina. *Mastozool. Neotrop.* **16**, 423–431 (2009).
75. Borah, S. B., Sivasankar, T., Ramya, M. N. S. & Raju, P. L. N. Flood inundation mapping and monitoring in Kaziranga National Park, Assam using Sentinel-1 SAR data. *Environ. Monit. Assess.* https://doi.org/10.1007/s10661-018-6893-y (2018).
76. De Barba, M. *et al.* Comparing opportunistic and systematic sampling methods for non-invasive genetic monitoring of a small translocated brown bear population. *J. Appl. Ecol.* **47**, 172–181. https://doi.org/10.1111/j.1365-2664.2009.01752 (2010).
77. Jachmann, H. & Bell, R. H. V. The use of elephant droppings in assessing numbers, occupance and age structure: A refinement of the method. *Afr. J. Ecol.* **22**, 127–141. https://doi.org/10.1111/j.1365-2028.1984.tb00686.x (1984).
78. Chaturvedi, R. K. & Sankar, K. *Laboratory Manual for the Physico-Chemical Analysis of Soil, Water and Plant* (Wildlife Institute of India, 2006).
79. Colwell, R. K. & Elsensohn, J. E. EstimateS turns 20: Statistical estimation of species richness and shared species from samples, with non-parametric extrapolation. *Ecography* **37**, 609–613. https://doi.org/10.1111/ecog.00814 (2014).
80. Colwell, R. K. *et al.* Models and estimators linking individual-based and sample-based rarefaction, extrapolation and comparison of assemblages. *J. Plant Ecol.* **5**, 3–21. https://doi.org/10.1093/jpe/rtr044 (2012).
81. Dormann, C. F., Gruber, B. & Fründ, J. Introducing the bipartite package: Analysing ecological networks. *R News* **8**, 8–11 (2008).
82. Barton, K. & Barton, M. K. Package 'MuMIn'. R package version, **1** (2019).
83. Harrell Jr, F. E. & Harrell Jr, M. F. E. Package 'Hmisc'. *CRAN2018*, **2019**, 235–236 (2019).
84. Wei, T. *et al.* Package 'corrplot': Visualization of a correlation matrix. *Statistician* **56**, 316–324 (2017).

Acknowledgements

This study was funded by the Department of Science and Technology, Government of India (Grant No. SR/SO/AS-28/2012) through the project entitled "Pattern of biomass production by wetlands and its use by wild ungulates in Kaziranga landscape". We are grateful to the Department of Environment and Forests, Assam for granting us permission to carry out this research. We express our sincere gratitude to Mr. N. K. Vasu and Mr. M. K. Yadava, former Park Directors, Kaziranga National Park for their support in the field. We thank Mr. Seal Sharma, former Divisional Forest Officer, Kaziranga National Park and Shri Rabindra Kumar Sharma, Research Officer, Kaziranga National Park for facilitating the fieldwork. We thank the Director and the Dean at the Wildlife Institute of India for providing logistic support and encouragement. We thank Dr. Chongpi Tuboi and Dr. K. Muthamizh Selvan for helping us at the initial stage of the fieldwork, Zeeshan Ali for preparing the maps, and Amanat Kaur Gill for help in editing the manuscript.

Author contributions

S.A.H. developed the concept, raised funds and design the research methods. A.D. and M.S. collected the field data. A.D. conducted the experiment and analyzed the data. R.B. and G.G.V. facilitated the field data collection. A.D. and S.A.H. wrote the manuscript. A.D., S.A.H., M.S. and R.B. reviewed and edited the manuscript.

Competing interests
The authors declare no competing interests.

Additional information
Supplementary Information The online version contains supplementary material available at https://doi.org/10.1038/s41598-021-04295-4.

Correspondence and requests for materials should be addressed to S.A.H.

ASIAN GRASSLAND CONFERENCE 2022

19-21 April 2022
Virtual Conference

CERTIFICATE

OF PARTICIPATION

THIS IS THE CERTIFY THAT

Anita Devi

attended
the Asian Grassland Conference
which was held online on 19 - 21 April 2022.

On behalf of the Organising Committee

Didem AMBARLI
Chair

Alla ALEKSANYAN

Stephen VENN

Frank YONGHONG LI

Jianshuang WU

eDGG Grassland research and conservation

IAVS

INNER MONGOLIA UNIVERSITY 1957

ASIAN GRASSLAND CONFERENCE 19-21 APRIL AGC2022

ASIAN GRASSLAND CONFERENCE

19-21 April 2022

Virtual Conference

BOOK OF ABSTRACTS

OP03

BIOLOGICAL INVASION BY LIVESTOCK AND DOGS IN WET GRASSLANDS OF BRAHMAPUTRA FLOODPLAINS OF ASSAM AFFECTING ITS INTEGRITY

Anita Devi[1], Syed Ainul Hussain[1], Monika Sharma[1] & Ruchi Badola[1]

[1]*Wildlife Institute of India, Post Box # 18, Chandrabani, Dehra Dun 248001, Uttarakhand, India*

E-mail: *anushrn4@gmail.com*

Questions: Protected Areas are increasingly facing the challenges of livestock grazing and incidents of feral dogs interacting with wildlife, increasing the probability of transmission of zoonotic diseases. Additionally, livestock competes with wild ungulates for forage, pushing the wild ungulates to inferior habitats. Grazing by livestock also alters the vegetation structure, with a preponderance of invasive plant species. The dogs (feral, stray or domestic) deplete the prey base for carnivores. Expansion of human settlements around the Kaziranga Tiger Reserve (KTR), a wet grassland in Assam, India, has increased the livestock and dog populations around the reserve. The impact of these changes is poorly studied. This study aims to provide information on the incidence of livestock grazing, the presence of dogs, and identifying its consequence on the integrity of KTR.

Methods: The fieldwork was conducted from January 2014 to May 2016. Observations were recorded from three habitats: tall grassland (TG), short grassland (SG), and woodland. For livestock (buffalo, cow and goat), opportunistic sightings of their grazing were recorded. The observations of dogs chasing wild herbivores were also recorded.

Results: In 416 grazing observations, a total of 58,000 livestock individuals were recorded, of which the highest sightings were recorded from TG (90.53%), followed by SG (9.17%) and woodland (0.31%). Among livestock, cows with the highest number of individuals (n=40914) and mean group size (MGS) of 106.27 (±5.89) were recorded primarily from TG (92.66%), followed by SG (7.14%) and woodland (0.21%). Similarly, goats with 16,923 individuals and MGS of 42.31 (±1.56) were recorded mainly from TG (85.29%), followed by SG (14.15%) and woodland (0.56%). Buffaloes with 163 individuals and MGS of 27.17 (±4.09) were recorded only in TG. In 55 dog observations, 111 individuals with MGS of 2.02 (±0.20) were recorded chasing wild herbivores, of which the maximum numbers of chasings were recorded from TG (53.15%), followed by SG (45.95%).

Conclusions: We conclude that TG is under high pressure as compared to other habitat types due to livestock grazing. Among livestock, cows exert more grazing pressure on the KTR, which is exacerbated by dogs often attacking the wild animals. We recommend regular monitoring, regulating livestock grazing, formulating livelihood programmes for villagers to reduce livestock dependency, improving veterinary assistance and dog sterilization programmes to manage their population. However, scientific evidence is needed to understand the impact of biological invasion on the grasslands habitat dynamic, wild animals population, disease transmission, and competition.

OP45

GEOGRAPHICAL DISTRIBUTION AND DRIVERS OF BIODIVERSITY IN INNER MONGOLIA

Gang Feng[1]

[1]*School of Ecology and Environment, Inner Mongolia University*

E-mail: *qaufenggang@163.com)*

Geographical distribution of biodiversity is associated with multiple spatial and temporal scale factors, e.g., geological events, paleoclimate change, current climate, topographic heterogeneity, and local biotic interactions. However, so far, no studies has systematically assessed the links between these factors and biodiversity distribution in Inner Mongolia. This presentation will first introduce the geographic distribution of bird, mammals, plant and insect diversity, and then discussed their associations with paleoclimate change, current climate, topographic heterogeneity and local biotic interactions. In addition, this presentation will also talk about the effects of land use changes on similarities/beta diversity of bird communities across Inner Mongolian grassland. The results showed that in addition to the effects of regional climate factors, local biotic interactions (i.e., inter-specific competition and food diversity) are also highly correlated with geographical distribution biodiversity in Inner Mongolia. The conversion from nature grassland to woodland, cropland and residual area has significantly promoted the biotic homogenization of bird communities, in terms of dimensions of taxonomic, phylogenetic and functional diversity. These findings suggest that the massive human activities in this region has caused serious biodiversity loss. Future biodiversity conservation should avoid the further disturbance of human beings, pay more attention on the ecosystem restoration, and keep the whole ecosystem healthy and intact.

EDGG Grassland research and conservation

IAVS

INNER MONGOLIA UNIVERSITY

ASIAN GRASSLAND CONFERENCE 19-21 APRIL AGC2022

ASIAN GRASSLAND CONFERENCE

19-21 April 2022

Virtual Conference

Abstracts of Speed-Talk Poster Presentations*

*Ordered in alphabetically by surname

PS47

NEW ALIEN INVASIVE PLANT SPECIES IN THE FLORA OF ADJARA (GEORGIA)

Irakli Mikeladze[1]

[1]Institute of Phytopathology and Biodiversity, Batumi Shota Rustaveli State University (BSU), Kobuleti, Adjara,

E-mail: Georgia. irakli.mikeladze@bsu.edu.ge

Adjara floristic region is located in the South Western part of Georgia, on the Black Sea coast, at an altitude of 0-2995 m above sea level. Area 2919 km^2, is divided into two parts: coastal Adjara and inner mountainous Adjara. Floristically rich and various. There are over 2000 species, among them about 500 species are alien. Between them 178 species are of woody plants - trees and shrubs, the rest are herbaceous.

156 species of Adjara alien flora are of Mediterranean origin and it is 32% of the whole flora, 134 species (27%) of East Asian origin is on the second place, 108 species (22%) are of European origin, other continents are represented with the following number of species - North America 59, South America 23 and Australia 8.

The appearance of alien plants in Adjara is connected to the introduction of cultural plants. The introduction of southern (subtropical) plants and distribution into culture has been going on since ancient times.

At the end of the XIX century there were 134 alien species in the flora of Adjara. In the 1920s -168, in the forties 281, since 1950 the number of alien plants grow by 30-40 species in every 10 years, which reached to 450 species in 2010. After 2010 many new alien species were described by us.

As a result of research conducted the last period, we have described several new alien species, among them is remarkable dangerous invasive species, they are:

Sicyos angulatus L., - widely spread on the agricultural grounds, particularly maize field, citrus crops and represents as a serious weed for farmers. It is also found in semi-natural habitats, on the riverbanks and nearby territories, roadsides, mainly in the swampy and moist soils.

Solidago canadensis L., - wide spread in seaside on roadsides, canals, ruderal areas, tea plantation, cultivated fields, forest margins and semi natural areas. Its invasive potential is high.

Cenchrus longispinus (Hack.) Fernald (=*Cenchrus pauciflorus* var. *longispinus* (Hack.) Jansen & Wacht.) - at this stage it is not wide spread. Found in the Kobuleti lowlands, on the seaside dunes. But they are characterized by abundant fruiting and rapid spread. It is dangerous invasive plant.

Verbena brasiliensis Vell., - is spread out seaside Adjara, roadways, ruderal sites, abandoned pastures, forest margins and abandoned lawns. In spreading areas, it takes the dominant position and completely changes plant environment.

PS49

VEGETATION COMPOSITION OF WET GRASSLANDS OF KAZIRANGA NATIONAL PARK, ASSAM, INDIA

Monika Sharma[1], Anita Devi[1], Syed Ainul Hussain[1] & Ruchi Badola[1]

[1]Wildlife Institute of India, Post Box # 18, Chandrabani, Dehra Dun 248001, Uttarakhand, India.

E-mail: monikasharma77777@gmail.com

Questions: Wet grasslands are biologically diverse ecosystems maintained by climate, hydrology, soil condition, and management interventions. Climate change is threatening the biodiversity, vegetation composition and ecosystem processes of these grasslands directly by affecting rainfall and temperature and indirectly by extreme climate conditions. The wet grasslands in the Brahmaputra floodplains of Kaziranga National Park (KNP), Assam, India are maintained by annual floods and burning practices. The consequence of the change in the intensity of these processes to the vegetation composition of the park is understudied. Necessitating the up-gradation of the available information on vegetation composition of the park. This study aims to provide information on vegetation composition of KNP in terms of species groups *viz*., angiosperms, pteridophytes and gymnosperms; monocots and dicots; and growth forms such as grasses, sedges, climbers, herbs, ferns, shrubs and trees.

Methods: Information on the vegetation composition of the park was gathered through an extensive literature review of available offline and online scientific articles, reports and books between 1970 and 2020. Offline, the literature available in the Wildlife Institute of India's library was reviewed. Online, the literature available was accessed through search engines like Google Scholar, Research Gate, Mendeley and scientific databases like Shodhganga and Biodiversity Heritage Library, using keywords like 'flora of KNP, vegetation composition of KNP, medicinal plants and trees of KNP' for review.

Results: One thousand and five plant species belonging to 585 genera and 147 families were documented. Of these, 965 were angiosperms, followed by 39 pteridophytes and one gymnosperm. In angiosperms, the highest number of species were represented by dicots (n=691) followed by monocots (n=274). *Ficus* with 23 species was the dominating genera, followed by *Cyperus* (n=15) and *Pancium* (n=10). Poaceae with 134 species was the dominating family, followed by Leguminosae (n=82) and Compositae (n=38). Among seven growth forms, the highest number of plant species were documented in herbs (n=272), followed by trees (n=263), shrubs (n=187), grasses (n=133), climbers (n=78), ferns (n=38) and sedges (n=34).

Conclusions: We conclude that KNP is rich in terms of flora although more scientific studies are needed to explore the pteridophytes and gymnosperms of the area. In the future, updated information on the vegetation composition of KNP will provide baseline information to understand the effects of climate change on vegetation composition. Which will further help develop sustainable grassland species-specific conservation strategies.

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

30th ANNUAL RESEARCH SEMINAR

29-30 September 2016

Programme & Abstracts

© AC

Food habits of large herbivores in Kaziranga National Park, Assam

-Anita Devi

The successful management of sympatric large herbivores in a landscape requires knowledge on resource partitioning and overlap among them, as mammalian herbivore species coexist by partitioning the key niche dimensions of diet and habitat. This study aims to examine the diet composition of six large herbivore species, with varying body size, occurring sympatrically in Brahmaputra flood plains, Assam.

This study was carried out in Kaziranga National Park, Assam (428.71 km^2).

The food habits of one-horned rhinoceros (*Rhinoceros unicornis*), Asian elephant (*Elephas maximus*), wild buffalo (*Bubalus arnee*), swamp deer (*Rucervus duvaucelii*), hog deer (*Axis porcinus*) and sambar (*Rusa unicolor*) were examined through the micro-histological analysis of a total of 1975 faecal (both dung & pellet) samples collected during 2013-15. The forage availability was determined in terms of above-ground biomass via the harvest method wherein three replicates were clipped every month from 1 m x 1 m plots within ten enclosures of 10 m x 10 m. Forage preference and diet overlap was derived using Ivlev's Electivity Index and Pianka's Index, respectively.

The diet of large herbivores in Kaziranga comprised of 57-66 forage species in the dry season and 49-66 species in the wet season. Graminoids dominated the diet of all the species studied, except elephant and sambar. In both the dry and wet seasons, *Saccharum* spp. contributed the most to the diet of large bodied mammals such as elephant, rhinoceros, wild buffalo and sambar, whereas *Hemarthria compressa* contributed the most to the diet of hog deer. The diet of swamp deer was dominated by *Saccharum* spp. in the dry season and by *H. compressa* in the wet season. In the dry season, *Oxalis corniculata* was the most preferred forage species by all the studied species (IV 0.99) whereas, in the wet season, *Echinochloa crus-galli* was most preferred (IV 0.99). Results indicated a significant overlap in the diet of the six herbivores, in both the dry and wet seasons (Pianka's index - 0.86 and 0.89).

In the wet season, grasses are more nutrient rich, thus, graminoid dominated the diet of all the studied species. Rhinoceros, elephant, wild buffalo and sambar feed more on tall grasses while swamp deer and hog deer feed more on short grasses.

Keywords: Diet composition, dietary overlaps, forage preference, mega-herbivores, forage availability

Project Title	:	Pattern of biomass production by wetlands and its use by wild ungulates in Kaziranga landscape
Principal Investigator(s)	:	S.A. Hussain, Ruchi Badola, Gopi G.V.
Researcher(s)	:	Anita Devi (Project Fellow), Monika Sharma (Junior Research Fellow)
Funding Agency	:	Department of Science and Technology, Govt. of India
Project Duration	:	2013-2016

Patterns of biomass production by the wet grasslands of Kaziranga National Park

-Monika Sharma

Altered hydrology in the floodplains may affect the availability of consumable plant biomass to large herbivores, causing a cascading effect on the ecosystem. Thus, this study aims to examine the above ground biomass (AGB) productivity of the seasonally flooded grasslands of the Brahmaputra floodplains.

The study was carried out in Kaziranga National Park (KNP), Assam, characterised by the alluvial deposits of the Brahmaputra River and its tributaries.

The 'Harvest Method' was used to estimate the AGB production for a period of two years. Fifteen enclosures, 10 m x 10 m in dimension, were constructed, out of which nine were in areas that remain inundated for less than 6 months and are characterized by tall grass communities (TG) and six in areas that remain inundated for more than 6 months and are characterized by short grass communities (SG). To quantify the AGB production, the grassland vegetation close to the soil surface was harvested monthly from the enclosures in 1 m x 1 m quadrates in triplicates. The productivity assessment is based on 121 plant species recorded from these enclosures.

The overall mean biomass productivity was 8421.29 ± 824.01 g m^{-2} (N=18). In 2014, the mean annual productivity was 6658.08 ± 962.70 g m^{-2} and, in 2015, it was 10184.5 ± 1087.07 g m^{-2}. The overall productivity varied significantly among the two sampling years (t-test, p = 0.01). There was significant difference in AGB of TG, 5285.80 ± 682.09 g m^{-2}, and SG, 3135.49 ± 489.72 g m^{-2} ($p = 0.01$). AGB productivity is directly related environmental factors such as rainfall, number of rainy days and temperature. Overall, highest productivity was observed in the month of July in TG and during May in SG. Among TG*Saccharum* spp. was the highest contributor to biomass followed by *Alpinia nigra*, *Ipomea* sp., *Mimosa* sp. and *Cuphea procumbens*. In SG, *Hemarthria* sp. contributed the most to the AGB productivity followed by *Cynodon dactylon*, *Cyperus* sp., *Saccharum* spp. and *Lippia javanica*.

The overall biomass productivity between the two study years varied significantly, which could be due to the synergistic effects of varied precipitation, temperature and flooding of the grasslands and, subsequent, nutrient enrichment. Further analysis on the role of these environmental variables may reflect factors affecting the productivity of this dynamic ecosystem.

Keywords: Biomass production, grasslands, floodplains, temperature, precipitation.

Project Title	: Pattern of biomass production by wetlands and its use by wild ungulates in Kaziranga landscape
Principal Investigator(s)	: S.A. Hussain, Ruchi Badola and Gopi G.V.
Researcher(s)	: Monika Sharma (Junior Research Fellow), Anita Devi (Project Fellow)
Funding Agency	: Department of Science and Technology, Govt. of India
Project Duration	: 2013-2016