THE SCHOOL FOR FIELD STUDIES

# Mountain Ecology
# SFS 3060

**Syllabus**
**4 credits**

The School for Field Studies (SFS)
Center for Climate and Sustainable Futures (CCSF)
Paro, Bhutan

This syllabus may develop or change over time based on local conditions, learning opportunities, and faculty expertise. Course content may vary from semester to semester.

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## COURSE CONTENT SUBJECT TO CHANGE

***Please note that this is a copy of a recent syllabus. A final syllabus will be provided to students on the first day of academic programming.***

SFS programs are different from other travel or study abroad programs. Each iteration of a program is unique and often cannot be implemented exactly as planned for a variety of reasons. There are factors which, although monitored closely, are beyond our control. For example:

- Changes in access to or expiration or change in terms of permits to the highly regulated and sensitive environments in which we work;
- Changes in social/political conditions or tenuous weather situations/natural disasters may require changes to sites or plans, often with little notice;
- Some aspects of programs depend on the current faculty team as well as the goodwill and generosity of individuals, communities, and institutions which lend support.

Please be advised that these or other variables may require changes before or during the program. Part of the SFS experience is adapting to changing conditions and overcoming the obstacles that they may present. In other words, this is a field program, and the field can change.

## Course Overview

The kingdom of Bhutan lies in the eastern Himalayan typically characterized by extensive and numerous mountains and valleys, world's highest peaks and a diversity of vegetation and wildlife. The mountain environments dominate Bhutan and shape both the culture and ecology of the land. Within this compact and mountainous country, are an extraordinary diversity of ecosystems and habitats; Bhutan and the Eastern Himalayan region are globally recognized as one of the hotpots for the biodiversity.

In this course, we focus on mountains. What are the processes that form mountains and shape their ecological communities? We will begin by studying the physical environment of mountains — the geology and climate. Upon gaining an understanding of the physical environment, we will investigate the effect of elevation gradients on vegetation and highlight special features of mountain animals and the interaction between habitat and animal communities. How do mountains influence the distribution of biodiversity and how do scientists study ecology in mountainous environments? Finally, what are the threats to mountain regions in a rapidly changing world and what conservation tools are scientists and conservation biologists implementing to protect sensitive mountain environments and species?

## Learning Objectives

The objective of this course is to provide students the background and tools necessary to understand and study the mountain environments of Bhutan and to learn its fauna and flora. Through classroom lectures, discussions, seminars, field lectures, and field exercises, we will examine what makes the Eastern Himalayan region unique. Classroom and field lectures will provide core concepts and tools for inquiry, whereas field exercises will reinforce these concepts and allow students to practice scientific inquiry skills and data collection. In this course students will develop a conceptual and practical understanding of the ecological complexity of the Eastern Himalaya region. Specific learning objectives are the following:

1. Understand the geological history and biogeography of mountain regions in general and the Eastern Himalayan region specifically, while distinguishing characteristics of mountain environments that explain species distributions and speciation,
2. Learn the natural history, biology and ecology of organisms in Bhutan,
3. Employ field research methods and analytical tools, including qualitative and quantitative methods scientists and managers use to study and conserve biodiversity,
4. Gain an understanding of the challenge's mountain communities face and the unique and progressive conservation efforts being made in Bhutan and
5. Practice the scientific method, gain experience conducting collaborative research in a multidisciplinary learning environment and advance science communication skills.

## Assessment

Our goal is to conduct ongoing assessment of student learning throughout the course, and provide timely and constructive feedback. Some assignments encourage students to work together, to share ideas and knowledge. This allows students to take advantage of the range of backgrounds within the group. Assessment will be conducted on an individual basis, unless otherwise stated. The final course grade will be based on the following:

| Assessment Item | Value (%) |
|---|---|
| Participation (including ungraded FEXes) | 10 |
| Quiz: Plant Identification | 15 |
| FEX 1: Quantifying Ecological Data | 15 |
| FEX 2: Measuring plant communities along elevation gradient | 15 |
| FEX 3: Measuring aquatic macroinvertebrates | 15 |
| Final Exam | 30 |
| **TOTAL** | **100** |

### Participation (10%)

During this program we will travel through many eco-regions and rural communities. We expect that you will be an active observer, constantly observing the landscape, livelihoods, and culture and participating in discussions regarding these observations. Active participation includes constructive engagement with the full range of course activities, respectful awareness of Bhutanese cultural context, and responsible behavior as a group member who is involved in others' learning. There will be opportunities throughout the semester for constructive feedback.

### Quiz: Plant Identification (15%)

This exercise will enable students to identify the main plant species and major life zones of Bhutan. The students will be given field lectures on plant identification around the Centre's campus, along the elevational gradient covering temperate to sub-tropical region. There will be plant identification quiz in the class using sample specimens. Individual student will pick a favorite plant species and a write short description illustrating its phylogeny, habitat where it grows, its uses and how it is propagated. A detailed handout will be provided for this FEX.

### Graded Field Exercises (FEX) (45%, 15% each)

Field exercises are designed for students to learn and practice a series of different field techniques to collect data on biodiversity. You will learn how to use these techniques, collect data, and perform statistical tests and interpretation of the results. Handouts will accompany each FEX, which will ask students to interpret their findings and reflect on study design and improvement.

**Quantifying Ecological Data (15%)**

This exercise will introduce students how to collect ecological data, analysis, and make inferences about the ecological phenomena.

**Measuring Plant Communities Along an Elevation Gradient (15%)**

Elevation transects are important natural experiments for ecologists to understand plant and animal responses to environmental gradients. We will observe plant and animal distributions and document changes in species occurrence and richness along a gradient spanning the mountain top and valleys and consider how climate change may affect these communities. We will document biodiversity along elevational gradient by dividing the class into groups. Each group will conduct a detailed survey of life forms in series of plots. Students will identify the plant species and measure woody trees for their DBH, height and other attributes of the trees within the plot. Additionally, the group will collect and record ecologically important morphological characteristics. Using these data, the students will estimate total biomass, calculate biodiversity index and other ecologically important bio-indicators. The surveys will cover altitudinal gradient from valley bottom to mountain top. Each group should produce a comprehensive written report covering different aspects of the exercise.

**Measuring Freshwater Macroinvertebrates (15%)**
Aquatic invertebrate communities are determined by resources available in streams, rivers, and lakes and are often influenced heavily by pollution. We will survey aquatic sites, observing how flow rates influence invertebrate communities. Students will use standardized survey techniques and keys to identify aquatic invertebrate species and summarize their findings in a short report.

**Final Exam (30%)**
One final comprehensive final exam will be administered, at the end of the course. You will be examined on what you have been exposed to in class (lectures, discussions, etc.), the field, and readings. The exams will challenge students to draw on multiple concepts and experiences, and to synthesize information.

## Grading Scheme

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| A | 95.00 - 100.00% | B+ | 86.00 - 89.99% | C+ | 76.00 - 79.99% | D | 60.00 - 69.99% |
| A- | 90.00 - 94.99% | B | 83.00 - 85.99% | C | 73.00 - 75.99% | F | 0.00 - 59.99% |
| | | B- | 80.00 - 82.99% | C- | 70.00 - 72.99% | | |

## General Reminders

**Honor Code/Plagiarism** – SFS places high expectations on their students and we hold students accountable for their behaviors. SFS students are held to the honor code below. SFS has a zero-tolerance policy towards student cheating, plagiarism, data falsification, and any other form of dishonest academic and/or research practice or behavior. Using the ideas or material of others without giving due credit is cheating and will not be tolerated. Any SFS student found to have engaged in or facilitated academic and/or research dishonesty will receive no credit (0%) for that activity.

> *"SFS does not tolerate cheating or plagiarism in any form. While participating in an SFS program, students are expected to refrain from cheating, plagiarism and any other behavior which would result in a student receiving credit for work which they did not accomplish on their own. Students are expected to report any instance of cheating or plagiarism by others."*

**Deadlines** – Deadlines for written and oral assignments are instated to promote equity among students and to allow faculty ample time to review and return assignments before others are due. As such, deadlines are firm; extensions will only be considered under extreme circumstances. Late assignments will incur a penalty of 10% of your grade for each day you are late. After two days past the deadline, assignments will no longer be accepted. Assignments will be handed back to students after a one-week grading period. Grade corrections for any assessment item should be requested in writing at least 24 hours after assignments are returned. No corrections will be considered afterwards.

**Content Statement** – Every student comes to SFS with unique life experiences, which contribute to the way various information is processed. Some of the content in this course may be intellectually or emotionally challenging but has been intentionally selected to achieve certain learning goals and/or showcase the complexity of many modern issues. If you anticipate a challenge engaging with a certain

topic or find that you are struggling with certain discussions, we encourage you to talk about it with faculty, friends, family, the HWM, or access available mental health resources.

**Participation** – Since we offer a program that is likely more intensive than you might be used to at your home institution, missing even one lecture can have a proportionally greater effect on your final grade simply because there is little room to make up for lost time. Participation in all components of the course is mandatory, it is important that you are prompt for all activities, bring the necessary equipment for field exercises and class activities, and simply get involved.

## Course Content

**Type- L:** Lecture, **FL:** Field Lecture, **GL:** Field Lecture, **FEX:** Field Exercise, **D:** Discussion

***Required readings are in bold**

| *No* | *Title and outline* | *Type* | *Time (hrs)* | *Readings* |
|---|---|---|---|---|
| ME 1 | **Course Overview**<br>Course Objectives, Syllabus, Field Exercises, Deadlines, Questions and Expectations for semester. | L, D | 1.0 | |
| | **Mountain Physical Environments** | | | |
| ME 2 | **The General Introduction to Ecology** | L, D | 1.0 | **Smith and Smith 2006 (Chapter I)** |
| ME 3 | **Biogeography of Himalayas**<br>Why are mountains located where they are? How did they get there? We'll explore the physical origins of mountains, theories of mountain building, and how our changing ideas about mountains and their genesis have shaped our engagement with them with particular focus on Himalayas. | L, D | 1.0 | **Mini, 1974**<br>**Smethurst, 2010**<br>Foggin, 2016<br>Sayre et al, 2018<br>Pandit et al., 2014 |
| ME 4 | **Himalayan geology and soils**<br>We will learn about basics of Himalayan geology and soils. We will discuss various implications of geology and soil. | L, D | 1.0 | **Crowther et al, 2019**<br>Harrison, 1992 |
| ME 5 | **Mountain Climate**<br>How do mountains affect climate? How are mountains shaped by climate? What are the geological processes in mountainous ecosystems? We will examine how elevation affects atmospheric processes and discuss an ecological manifestation of climate change on mountain systems. | L, D | 1.0 | **Spicer, 2017**<br>**Barry, 2008 (Ch.1 and 5)**<br>Srinivasan, 2013 |
| ME 6 | **FEX I: Quantifying Ecology**<br>How do we deal and understand ecological data? Handout and analysis guidelines will be provided. | L, FEX | 4.0 | **Smith and Smith 2006 (Chapter 1)** |
| | **Mountain Lifeforms and Biodiversity** | | | |
| ME 7 | **Terrestrial Life Zone Ecology of Bhutan Himalaya**<br>We will learn and discuss different life forms (biomes), their special characteristics and implications for biodiversity conservation including cloud forests. | L, D | 1.0 | **Wangda and Ohsawa, 2011**<br>Singh, 1987<br>Wangda and Ohsawa, 2006<br>Lugo, 1999<br>Banerjee, 2016 |

| *No* | *Title and outline* | *Type* | *Time (hrs)* | *Readings* |
|---|---|---|---|---|
| ME 8 | **Adaptations of Organisms in the Mountains**<br>What are the basic requirements for plants and animals for their growth and development? How do they adapt to different environment? What is the adapting mechanism of plants and animals in the mountainous environment? | L, D | 1.0 | **Halbritter et al, 2018**<br>**Fjeldsa et al, 2013**<br>Badgley, 2008<br>Manish and Pandit, 2018 |
| ME 9 | **Visit to National Takin Preserve**<br>During the visit to National Takin Preserve, students will learn about the ecology of Bhutan's national animal takin, history of takin too, mythology associate with Takin and Lam Drukpa Kuenley. conservation threats of takins. Students will also observe other wildlife present at the preserve. | FL | 3.0 | **Sangay et. al., 2016**<br>**Badgley, 2008** |
| ME 10 | **Field Survey Method I** (Wildlife Survey Methods)<br>We will learn different survey methods to study animal communities and learn how to handle basic equipment for measurement of various environmental variables. We will also learn to develop data recording methods. | L, D | 1.0 | **Oli and Mills, 2013** |
| ME 11 | **FEX II: Surveying Large Mammals Using Camera Traps**<br>Here we will learn methods to study large mammals using camera trapping in different micro-sites of Paro Valley. | FEX | 4.0 | **Kelly et al., 2013** |
| ME 12 | **Conservation genetics**<br>Here students will learn genetics as an important tool for both monitoring wildlife and understanding ecological processes. We will also introduce how noninvasive genetic sampling has opened the horizon for the application of genetics to many wildlife species that previously could not be effectively studied. | L, D | 1.0 | **Janecka et al., 2013**<br>**Dendup et al., 2023** |
| ME 13 | **Field Survey Method II** (Plant and Vegetation Survey Methods)<br>We will learn about different sampling methods for ecological studies of plant communities including dendrochronology and learn how to handle different equipment used for surveys. | L, D | 1.0 | **Lõhmus et al., 2018** |
| ME 14 | **Fundamentals of Plant Identification Skills**<br>We will understand the basic morphological characteristics of leaves, fruits, flower, and other parts of the of plant species to use in plant species classification system. | L, D | 1.0 | **Wondafrash, 2008** |
| ME 15 | **FEX III: Plant Communities along Elevational Gradient**<br>We will explore and identify major life forms, identify plant species and their floral characteristics on different along the elevational gradient. Each student will make and submit a vegetation profile map along elevational gradient from Paro Woochu to Chelela top. | L, D | 4.0 | **Web based (3, 4, 6 and 7)** |
| ME 16 | **Avian Ecology and Migration**<br>Learn about high elevation bird species, adaptations, and migration of some key bird species of the Bhutan Himalayas. | GL, D | 1.0 | **Zhang et al, 2017**<br>**Norbu, 2013**<br>Hawkes et al. 2011<br>Hu et al, 2018 |

| *No* | *Title and outline* | *Type* | *Time (hrs)* | *Readings* |
|---|---|---|---|---|
| ME 17 | **FEX IV: Avian Mist-netting and Field Census Techniques**<br>Learn a few fundamentals on avian research through mist netting and field survey of birds along an elevational gradient | FEX | 4.0 | **Pandit et al, 2016**<br>**Acharya and Vijayan, 2017**<br>Amrhein, 2012 |
| ME 18 | **FEX V: Measuring Floral Biodiversity**<br>Different types of sampling methods and basic calculations of biodiversity statistics will be taught in this class. The output from this class will be applied in practice for descriptive statistics of forest structure and composition, estimates of forest biomass, forest stock increment, and other biodiversity indexes in life zone inventory field exercise. | FEX | 4.0 | **Wangda and Ohsawa, 2011**<br>**Oshawa, 1987** |
| ME 19 | **Mountain Aquatic Environments**<br>What organisms are found in different wetland habitats? What are their adaptation mechanisms? We will discuss wetland ecosystems and understand basic requirement for macroinvertebrate survival in those ecosystems. | L, D | 1.0 | **Von Oheimb, 2013**<br>**Verhoeven, 2006**<br>Sherub et al., 2013 |
| ME 20 | **FEX VI: Measuring Fresh Water Macroinvertebrates**<br>Here we will also learn to conduct baseline survey methods of aquatic environment (water velocity, water pH and total dissolved substance. | FEX | 4.0 | Mackey,1984 |
| ME 21 | **Fundamentals of Terrestrial Invertebrates**<br>Here we will learn about the role of terrestrial invertebrates and in functioning of the ecosystems in different microsites. | GL, D | 1.0 | **Joshi et al., 2008** |
| ME 22 | **Counting Water Birds**<br>During our stay at CNR, we will conduct water bird Survey. Students will be introduced to point count sampling and distance sampling. | FL | 3.0 | |
| ME 23 | **FEX VI: Counting Black-Necked Cranes at Phobjikha/Bioblitz**<br>Here we will explore black-necked crane habitat, count cranes and observed basic behavior such as preening, sequential vigilance and estimate walking distance during feeding. We will aslo visit BNC Center and watch documentory on BNC and threats of BNC conservation in Bhutan | FL, FEX | 4.0 | **Namgay and Wangchuk, 2016**<br>ICIMOD and RSPN, 2014<br>Lind, 2010<br>Zhongqiu, 2014 |
| ME 24 | **Population Ecology of High Mountains**<br>We will learn about dynamics of population structure which relates to density, foraging, habitat requirement especially of wild animals. | L, D | 1.0 | **Tamma, 2016**<br>**Amrhein,2012** |
| ME 25 | **Large Mammals Ecology of Bhutan**<br>Discussion of Large Carnivore Conservation and keystone species conservation such as tiger and its implications conservation of forest ecosystems. | GL | 1.0 | **Tempa et al, 2013**<br>**Carter & Lindell, 2016**<br>Lindsey et al, 2017 |
| ME 26 | **Ecology of Small Himalayan Mammals**<br>Here we will learn the basic and fundamental of small mammal species of Bhutan. | L, D | 1.0 | **Hoffmann, 2010**<br>**Flowerdew, 1976** |

| *No* | *Title and outline* | *Type* | *Time (hrs)* | *Readings* |
|---|---|---|---|---|
| ME 27 | **Species Interactions in Mountainous Environment**<br>We will examine multiple species interactions (interspecific competition, predation, and population regulation, parasitism) and their influence on demographic processes and as agents of natural selection. Are montane communities more disease resistant than lowland communities, or have montane organisms escaped lowland disease vectors? | L, D | 1.0 | **Zamora-Vilchis et al, 2012;**<br>**Telwala et al, 2009**<br>Hobbs, 2006 |
| ME 28 | **Plant ID Quiz** | | 1.0 | |
| | **Mountain Disturbance Ecology** | | | |
| ME 29 | **Mountain Forest and Disturbance Ecology**<br>We will identify major disturbance regimes such as climate change in mountainous terrain including human use of mountain forests in Bhutan and their implications on sustainable management of these mountainous ecosystems. | L, D | 1.0 | **Manral, 2017**<br>Dortch, 2009<br>Bajracharya, 2014<br>Beran et al, 2018<br>Jekins et al,2013 |
| ME 30 | **Case Study: Response of Old growth Forests to Failure of Monsoon**<br>We will closely examine ecological processes in relation to forest and water. We will also examine the risk of old growth forests in relation to climate change. | GL, D | 1.0 | **Wangdi et al., 2023**<br>Ellison et al, 2017<br>Price et al, 2013 |
| ME 31 | **Capstone: How will Mountain Ecosystems respond to Climate Change**<br>Here we will discuss about how mountain species both plants and animals will be affected by climate change and how they will adopt to these emerging threats. | L, D | 1.0 | |
| ME 32 | Final Exam Review | | 1.0 | |
| | **Total** | | **57** | |
| | **UMN Instructional Hours*** | | **68.4** | |

**UMN defines an instructional hour as a 50-minute block. SFS syllabi are written in full 60-minute hours for programming purposes. Therefore 50 full hours = 60 UMN instructional hours (for four credit courses) and 25 full hours = 30 UMN instructional hours (for two credit courses).*

## Reading List

***Required readings are in bold**


1. Abdin, M. Z., Kiran, U., Kamaluddin, A. A. (2017). Plant Biotechnology: Principles and Applications || Plant Adaptation in Mountain Ecosystem., 10.1007/978-981-10-2961-5(Chapter 10), 249–271. doi:10.1007/978-981-10-2961-5_10.
2. **Amrhein, V., Scaar, B., Baumann, M., Minéry, N., Binnert, J.-P., & Korner-Nievergelt, F. (2012).** Estimating adult sex ratios from bird mist netting data. Methods in Ecology and Evolution, 3(4), 713–720. doi:10.1111/j.2041-210x.2012.00207.x.
3. **Arenas-Castro, S., Fernández-Haeger, J., & Jordano-Barbudo, D. (2015).** A Method for Tree-Ring Analysis Using Diva-Gis Freeware on Scanned Core Images. Tree-Ring Research, 71(2), 118–129. doi:10.3959/1536-1098-71.2.118.

4. Banerjee, A., & Bandopadhyay, R. (2016). Biodiversity hotspot of Bhutan and its sustainability. Current Science,110(4), 521-527. doi:10.18520/cs/v110/i4/521-527.

5. **Barry, R.G. (2008).** Mountain Weather and Climate, Cambridge.

6. Beran, L., & Dyckhoff, H. (2018). Global Biomass Supply and Sustainable Development. Human and Environmental Security in the Era of Global Risks, 291–316. doi:10.1007/978-3-319-92828-9_15.

7. Broll G., Hiller B., Bednorz F., Müller G., Reineke T. (2005) Guideline for Describing Soil Profiles in Mountain Ecosystems. In: Broll G., Keplin B. (eds) Mountain Ecosystems. Springer, Berlin, Heidelberg. https://doi.org/10.1007/3-540-27365.

8. CIFPOR (2006). A Field Manual for Rapid Vegetation Classification and Survey for general purposes. Indonesia.

9. **Cannon, P.F., Hywel-Jones, N.L., Maczey, N., Norbu, L., Tshitila, Samdup, T., and Lhendup, P. (2009).** Steps towards sustainable harvest of Ophiocordyceps sinensis in Bhutan. Biodivers Conserv (2009) 18:2263–2281 DOI 10.1007/s10531-009-9587-5.

10. **Carter, N.H. and J.D.C. Lindell. (2016).** Co-adaptation is key to coexisting with large carnivores. Trends in Ecology and Evolution 31: 575-578.

11. **Crowther, T.W., van den Hoogen, Wan, J., Mayes, M.A., Keiser, A.D., Mo, L., Averill, Maynard, C.,D.S. (2019).** The global soil community and its influence on biogeochemistry. Science365, eaav0550.

12. Dortch, J. M., Owen, L. A., Haneberg, W. C., Caffee, M. W., Dietsch, C., & Kamp, U. (2009). Nature and timing of large landslides in the Himalaya and Transhimalaya of northern India. Quaternary Science Reviews, 28(11-12), 1037–1054. doi:10.1016/j.quascirev.2008.05.002.

13. Ellison, D., Morris, C. E., Locatelli, B., Sheil, D., Cohen, J., Murdiyarso, D., … Sullivan, C. A. (2017). Trees, forests and water: Cool insights for a hot world. Global Environmental Change, 43, 51–61. doi:10.1016/j.gloenvcha.2017.01.002.

14. Ellis, E. C., Goldewijk, K. K., Siebert, S., Lightman, D., & Ramankutty, N. (2010). Anthropogenic transformation of the biomes, 1700 to 2000.Global Ecology and Biogeography,19(5), 589-606. doi:10.1111/j.1466-8238.2010.00540.x.

15. **Fjeldsa, J., R.C.K. Bowie, and C. Rahbek. (2012).** The role of mountain range in the diversification of birds. Annual Review of Ecology, Evolution and Systematics.

16. Foggin, J. M. (2016). Conservation Issues: Mountain Ecosystems. Reference Module in Earth Systems and Environmental Sciences. doi:10.1016/b978-0-12-409548-9.09199-5.

17. **Flowerdew, J. R. (1976).** Chapter 4: Ecological methods. Mammal Review, 6(4), 123–159. doi:10.1111/j.1365-2907.1976.tb00208.x.

18. Giri, N.,and Singh, O. P. (2013). Urban growth and Water Quality in Thimphu, Bhutan. Journal of Urban and Environmental Engineering, (7), 1, pp. 82–95, http://www.jstor.org/stable/26203392.

19. **Halbritter, A. H., Fior, S., Keller, I., Billeter, R., Edwards, P. J., Holderegger, R., … Alexander, J. M. (2018).** Trait differentiation and adaptation of plants along elevation gradients. Journal of Evolutionary Biology, 31(6), 784–800. doi:10.1111/jeb.13262.

20. **Harrison, T.M., Copeland, P. Kidd, W.S.F. and Yin, A. (1992).** Raising Tibet. Science, 255(5052), 1663–1670. doi:10.1126/science.255.5052.1663.

21. Haslett, J.R. (1997). Mountain Ecology: Organism Responses to Environmental Change || Mountain Ecology: Organism Responses to Environmental Change, an Introduction. Global Ecology and Biogeography Letters, 6(1), 3–6. doi:10.2307/2997522.

22. Hobbs, R. J., Arico, S., Aronson, J., Baron, J. S., Bridgewater, P., Cramer, V. A., . . . Zobel, M. (2006). Novel ecosystems: Theoretical and management aspects of the new ecological world order. Global Ecology and Biogeography, 15(1), 1-7. doi:10.1111/j.1466-822X.2006.00212.x.

23. **Hu, Y., Ding, Z., Jiang, Z., et al. (2018).** Birds in the Himalayas: What drives beta diversity patterns along an elevational gradient? Ecology and Evolution, (8):11704–11716.

24. **ICIMOD and RSPN (2014).** An integrated assessment of the effects of natural and human disturbances on a wetland ecosystem: A retrospective from Phobjikha Conservation Area, Bhutan. Kathmandu: ICIMOD.

25. **Jamtsho, K., Sridith, K. (2015).** Exploring the patterns of alpine vegetation of Eastern Bhutan: a case study from the Merak Himalaya. *SpringerPlus* (4), 304. https://doi.org/10.1186/s40064-015-1066-8.

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27. **Joshi, P. C., Kumar, K., & Arya, M. (2008).** Assessment of insect diversity along an altitudinal gradient in Pinderi forests of Western Himalaya, India. Journal of Asia-Pacific Entomology, 11(1), 5–11. doi:10.1016/j.aspen.2008.02.002.

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29. Koner, C., Paulsen, J., Spehn, E.M. (2011). Alps a definition of mountains and their bioclimatic belts for global comparisons of biodiversity data. Botany (2011) 121:73–78 DOI 10.1007/s00035-011-0094-4.

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35. Manish, K. and Pandit, M.K. (2018), Geophysical upheavals and evolutionary diversification of plant species in the Himalaya. PeerJ 6:e5919; DOI 10.7717/peerj.5919.

36. **Manral, Upma; Badola, Ruchi; Hussain, Syed Ainul (2017).** *Forest Composition and Structure Under Various Disturbance Regimes in the Alaknanda River Basin, Western Himalaya. Mountain Research and Development, 37(3), 310–322.* doi:10.1659/MRD-JOURNAL-D-16-00109.1

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