**Course : Science, Society and Sustainability**

**Credits : 4**

**Code: ES 2106/BIO 2106-1**

**Professor: Ghazala Shahabuddin**

**Description**

This course explores environmental sustainability in the Anthropocene, based on key ecological concepts such as diversity, energy transfer, ecosystems, population growth, food-webs and nutrient cycling. This course will be useful for students who wish to understand the scientific underpinnings of the sustainability concept in contemporary times, and the ways that they are deployed in current socio-political contexts. The course is designed primarily as an introduction to ecological thinking for students from both natural and social sciences, based on analysis of complex environmental debates around climate justice, pollution control, sustainable harvest, ‘re-wilding’ and urban ecology, among others.

The theory lectures will alternate with class discussions (including student presentations) on current environmental concerns and articles. 30-40 pages of reading from journal articles, newspapers and books will be prescribed as background reading each week. There will be a day-long field trip to study urban ecology within Delhi NCR which will form a significant component of learning in this course.

**Learning Objectives**

Students will learn to apply scientific principles to current environmental challenges and analyse the concept of sustainability in a range of social-ecological situations.

**Assessment**

Course evaluation will be based on a combination of in-class essays, a mid-term exam and a final term paper (based on the field trip). In addition, students will be graded on their presentations and quality of their participation in class discussions. Attendance will be graded; students are expected to attend 90% of classes.

**Weightage of Assessments:**

Participation in class discussions/presentations: 25%

In-class short essays (2): 20%

Mid-term Exam: 25%

Final Term Paper: 25%

Attendance: 5%

**List of Topics/Modules with Readings**

**Module 1: Sustainability in the Anthropocene**

The students will be introduced to the varying notions of social and ecological sustainability, using a historical perspective on the Anthropocene. Discussion will be invited on the relevance and application of science in addressing environmental concerns and sustainability, based on a current environmental crisis.

**Readings:**

Corlett, R. 2015.The Anthropocene concept in ecology and conservation. *Trends in Ecology and Evolution* 30(1):36-41.

**Module 2,3:**

**Ecosystem Concept: Structure and Energy Flows**

We will explore ecosystems and their different components. Basic tenets of ecology will be covered, including energy flow, primary productivity, foodchains and foodwebs will be covered in addition to basic tenets of ecology.

**Readings:**

Krebs, C.J. 2009. Chapter 22: Ecosystem Metabolism I: Primary Production (Pgs 451-473); Ecosystem Metabolism II: Secondary Production (Pgs 475-495). In *Ecology: The Experimental Analysis of Distribution and Abundance*. Benjamin Cummings Publications.

**Module 4: Soil, Water and Nutrients**

This module focusses on soils, and nutrient cycling, with the aim to introduce the students to ecosystem-level thinking about process. We study the underlying principles of flow of matter through ecosystems and the earth’s biogeochemical cycles, taking nitrogen, carbon and phosphorus as examples.

**Reading:**

Krebs, C.J. 2009. Chapter 24: Ecosystem Metabolism III: Nutrient Cycles (Pgs 497-519). In *Ecology: The Experimental Analysis of Distribution and Abundance*. Benjamin Cummings Publications.

**Module 5: Sustainable Agriculture**

The application of soils and nutrient cycles for ecological health will be discussed, using the example of organic farming. Two short movies on organic farming will be used in this module, along with popular reading, to discuss sustainability in agriculture.

**Readings**

Pollan, M. 2006. Chapter 2: Farm, pp. 32-56. In: *The Omnivore’s Dilemma*. Penguin Books, USA.

Renard, D. and Tilman, D. 2021. Cultivate biodiversity to harvest food security and sustainability**.** *Current Biology* *31*, R1141–R1224,

Nabhan, G.P. 1997. Let us Now Praise Native Crops, An American Cornucopia. In:*Cultures of Habitat: On Nature, Culture and Story*. Counterpoint, Washington D.C.

**Movies:**

Organic Farming in Auroville

<https://www.youtube.com/watch?v=5iOTq6kb4qM>

Rice diversity and cultivation

<https://www.youtube.com/watch?v=C08FAa-Vlj0>

**Module 6: Understanding Pollution**

In this module, students will read the environmental classic by Barry Commoner. They will then be involved in a classroom modelling exercise to apply ecological principles to a contemporary pollution concern.

**Readings:**

Commoner, B. 1971. *The Closing Circle, Nature, Man, Technology.* Chapter 2: The Ecosphere (Pgs 14-48); Chapter 4: Los Angeles Air (Pgs 66-80). Alfred P. Knopf, New York, USA.

**Module 7: World Climates**

World climates provide the template on which ecosystems are developed and perpetuated. In this module, the geographic factors underlying climatic regimes across the world, will be studied. The climatic factors that are key to formation of a range of natural habitats and ecosystems will be discussed. Students will be introduced to the features that characterize and distinguish the earth’s biomes, particularly climatic factors and topography.

**Readings:**

Ricklefs, R.E. & G. Miller. 2000. *Ecology* (Fourth Edition). Chapter 8: Climate, Topography and the Diversity of the Natural World (Pgs.138-161). W.H. Freeman & Co., New York.

**Module 8,9 : Ecosystems of the World**

This session will provide an introduction to the distribution and classification of terrestrial and aquatic biomes across the world. Students will also be introduced to the classification of vegetation types in India as laid out in Champion & Seth (1968). They will study the tropical rainforest ecosystem in detail with respect to the major limiting factors, historical anthropogenic imprint and biodiversity.

**Reading:**

Ricklefs, R.E. & G. Miller. 2000. *Ecology* (Fourth Edition). Chapter 8: Climate, Topography and the Diversity of the Natural World (Pgs.138-161). W.H. Freeman & Co., New York.

Erickson, C.E. 2014. Amazonia: The Historical Ecology of a Domesticated Landscape. Pp. 199-216.In Hecht, S., K.D. Morrison and C. Padoch (eds.) *The Social Lives of Forests, Past, Present and Future of Woodland Resurgence*. University of Chicago Press.

Terborgh, J. 1992. Diversity and the Tropical Rain Forest. Pgs 1-27 In Scientific American Books, New York, USA.

**Module 10. Science of Climate Change**

This module goes into the scientific evidence for climate change and global warming. The visible impacts on climate systems, biodiversity and economies will be discussed using the case study of Sunderbans, one of the areas hard-hit by climate change.

**Readings:**

Climate Change and the Indian Ocean by Down to Earth

<https://www.youtube.com/channel/UCIB_MLJZL0T_s5OUuqhmbVA>

Kolbert, E. 2014. Chapter 8: The Forest and the Trees (Pgs.148-172) In: *The Sixth Extinction, An Unnatural History*. Bloomsbury, London.

Ghosh, A. 2019. Disastrous delta: Daily struggles against nature in the Sunderbans. Pp. 29-36 In. Ghosh, A. (Ed.). *The Tides of Life: Surviving Between the Margins.* Indira Gandhi National Centre for the Arts, India.

Mahmud, S. 2019. Adapting to change in the Sunderbans ecosystems: Lay people’s perceptions. Pp. 129-141 In. Ghosh, A. (Ed.). *The Tides of Life: Surviving Between the Margins.* Indira Gandhi National Centre for the Arts, India.

**Module 11. Technological vs. Nature-Based Solutions to Global Warming**

In this module, we focus on solutions to climate change, using nature-based solutions as an example.

**Readings:**

**F**leischman, F. et al. 2020. Pitfalls of Tree Planting Show Why we Need People-centered Natural Climate Solutions. *Bioscience* 70(11):947-950.

Dyke, J.G., W. Knorr and R. Watson. 2021. Why Net Zero Policies Do More Harm than Good. Pgs 39-52 in Bohm, S. and S. Sullivan (Eds) *Negotiating Climate Change in Crisis*. Open Book Publishers, Cambridge, UK.

Chazdon, R. and P. Brancalion. 2019. Restoring forests as a means to many ends. *Science*. 364, 24– 10 25.

Carbon capture & storage: <https://insideclimatenews.org/news/04122022/> carbon-removal-fossil-fuels-wyoming/

Promises and perils of the solar energy boom: https://www.wired.co.uk/article/india-solar-power

**Module 12: Population Growth and Regulation**

Concepts of populations, population structure, different parameters associated with populations, growth curves and population age structure will be covered. Mechanisms of population regulation will also be discussed.

**Readings:**

**K**ormondy, E.J. 1969. Concepts of Ecology (4th Edition). Chapter 10: Population growth and structure (Pgs 194-224). Prentice Hall, New Jersey.

**Module 13: Big Cats in Human Landscapes**

Applications of key concepts in population ecology to the real-life challenge of Bengal tiger conservation will be discussed, based on articles and news.

Sinha, N. 2021. Chapter 6: The Mother of Men and Tigers, The Tiger (*Panthera tigris*) (Pgs 113-142) In: In Wild and Wilful; Tales of 15 Iconic Indian Species. Harper Collins India, U.P.

Chundawat, R. 2018. Chapter 5: Tiger Society: Solitary Existence but Social Living (Pgs 75-122). In: The Rise and Fall of the Emerald Tigers, Ten Years of Research in Panna National Park. Speaking Tiger Publications, New Delhi.

Kaushik, N. 2018. Was it necessary to kill tigress Avni? Scroll, November 20, 2018

<https://scroll.in/article/902693/was-it-necessary-to-kill-tigress-avni>

**Module 14. Crocodiles for Sale: Sustainable Harvest as a Strategy**

Students will apply theories of population growth and regulation to sustainable harvest of wild species, including saltwater crocodiles. They will compare the socio-political and scientific contexts of sustainable harvest between two countries: Australia and India.

Quammen, D. 2003. *Monster of God, The Man-eating Predator in the Jungles of History and the Mind.* Chapter 4: Leviathan with a Hook (Pgs 127-207). WW Norton & Co., New York, USA.

**Module 15: Invasive Species**

Invasive species present a useful system to understand basic ecological processes such as competition and population regulation. At the same time, invasive ecology has immense implications for socio-economic stability and ecosystem services, and requires detailed study. In this module, students will apply the basics of community ecology to understanding invasives and their socio-economic impacts.

Simberloff, D. et al. 2013. Impacts of biological invasions: what’s what and the way forward. *Trends in Ecology and Evolution* 28(1): 58-66.

Ricciardi, A., M.E. Palmer and N.D.Yan. Should Biological Invasions be Managed as Natural Disasters? *BioScience* 61: 312-317.

Pearce, F. 2015. *The New Wild: Why Invasive Species will be Nature’s Salvation*. Beacon Press, Boston, USA.

**Module 16, 17: Biodiversity: Pattern and Process**

This module will introduce students to the concept of biodiversity. They will learn how to characterise communities through commonly used metrics such as species richness, abundance, evenness, diversity indices and similarity. The ideas of ecological niche and resource partitioning will be introduced. Global patterns of biodiversity and their underlying drivers will also be discussed. These concepts will be applied to understanding biodiversity impacts of land use change at local and landscape scales using the example of the Himalayan state of Mizoram.

**Reading:**

Krebs, C.J. 2009. Chapter 19: Community structure in Space: Biodiversity (Pgs 377-400). In *Ecology: The Experimental Analysis of Distribution and Abundance*. Benjamin Cummings Publications.

Mandal, J. and T.R. Shankar Raman. 2016. Shifting agriculture supports more tropical forest birds than oil palm or teak plantations in Mizoram, northeast India. *The Condor* 118: 345-359.

**Module 18,19: Interspecies Interactions**

In the first part of this module, various interspecific interactions such as predator-prey relations, competition and plant-animal relations will be covered. Historic lab and field experiments in community ecology will be discussed. The second part of this module deals with food web theory, as a way to describe and understand the complexity in the ecological world. The attributes of food webs that explain community persistence will be examined. The notion of ‘keystone species’ will be discussed.

**Background Reading:**

Krebs, C.J. 2009. Chapter 20: Community Dynamics I: Predation and Competition in Equilibrial Communities (Pgs 401-424). In *Ecology: The Experimental Analysis of Distribution and Abundance*. Benjamin Cummings Publications.

Dinerstein, E. 2003. Endangered Phenomena: Rhinoceros as Landscape Architects In: Dinerstein E. *The Return of the Unicorns. The Natural History and Conservation of the Greater One-Horned Rhinoceros*. Pages 153-177. Columbia University Press.

**Module 20, 21: Field Trip (Urban Ecology)**

Students will be taken on a day-long field trip to the Aravalli Hills of Delhi NCR to study the socio-political and ecological contexts of urban sustainability, with a focus on ecosystem restoration. They will attempt to apply the scientific principles learnt in the course to the real-life examples of forest restoration; and also use a multidisciplinary lens to understand the usefulness and efficacy of tropical dry forest restoration as a ‘re-wilding’ strategy.

**Module 22: Ecological Succession**

**Description:**

Many of the spatial patterns in plant communities that we observe today reflect historical and ongoing ecological processes. The plant and animal communities are likely to be very different from those that existed a few decades ago and bear the imprint of both ongoing ecological processes and human activities. We will explore the successional patterns in plant communities and how these patterns manifest in variations in communities of animals and plants that depend on them.

**Reading:**

Krebs, C.J. 2009. Chapter 18: Community Structure in Time: Succession (Pgs 352-376). Ecology (6th Edition). In *Ecology: The Experimental Analysis of Distribution and Abundance*. Benjamin Cummings Publishing, USA.

**Module 23: Social-ecological Principles for Restoring Forests**

Restoring forests on degraded land so as to recreate productive ecosystems is now being taken up on a large scale across the world. Effective restoration requires not just sound ecological knowledge of species and their interactions, but also recognition of the socio-economic matrix within which it is undertaken. Discussion will take place around three short videos on forest restoration from different parts of the world.

**Movies:**

Restoring forests in New Zealand:

<https://www.youtube.com/watch?v=3VZSJKbzyMc>

Restoring Forests in Annamalai

<https://www.youtube.com/watch?v=biazSyLYsEY>

Restoration in Aravalli Biodiversity Park, Gurgaon

<https://www.youtube.com/watch?v=1ymsJtk25nM>

**Module 24: Sustainability and the City**

Urban ecology has come to the forefront in recent decades given the rapid expansion of urbanization into the countryside, rural-to-urban migration of people and numerous environmental problems that exist. The city is a place where social churning is visible, yet history constrains positive change in many ways. This module aims to introduce the students to the social-ecological complexity of the city through a comparative approach. Students will attempt to discover temporal trends and socio-political drivers of ecological change in the Aravalli Hills of Delhi NCR through the readings.

**Readings**

Vikas, M. 2019. Conservation in urban spaces: People-wildlife interactions and management of Delhi’s forests. Pp 55-82 In Shahabuddin, G. and Sivaramakrishnan, K. (Eds). *Nature in the New Economy: People, Wildlife and the Law in India*. Orient Blackswan, Delhi, India.

Gururani, S. 2018. When land becomes gold: Changing political ecology of the commons in a rural-urban frontier. Pp. 107-125 in: MollettS. And Kepe, T. (eds.) *Land Rights, Biodiversity Conservation and Justice*. New York, London: Routledge.

Agarwal, R. 2014. The Fight for an Urban Forest: The Delhi Ridge. Pp. 107-130 In Rangarajan, M., M.D. Madhusudan and G. Shahabuddin (Eds.) *Nature Without Borders*. Orient Blackswan, India.

Baviskar A. 2020. *Uncivil City: Ecology, Equity and the Commons in Delhi.* Pgs 169-194. Sage Publications and Yoda Press, India. Chapter 7: 169-194.

**Module 25,26: Reintroduction of Carnivores**

Reintroduction of carnivores to areas where they occurred earlier, a form of ‘rewilding’, has become widespread in the 20th century. The key rationale employed here is that the reinstatement of the top-down forces of predation prevents ‘ecosystem collapse’. In this module we examine one of the most celebrated cases of reintroduction- that of gray wolves to the Greater Yellowstone ecosystem in North America- in relation to debates on bottom-up and top-down trophic forces.

With this framework, students will take up group assignments to evaluate carnivore reintroductions that have taken place in India: tigers in Sariska and cheetahs in Kuno-Palpur- from social, political and ecological perspectives.

**Readings:**

Ripple, W.J., T.P. Rooney and R.L. Beschta. 2010. Large Predators, Deer and Trophic Cascades in Boreal and Temperate Ecosystems. Pp. 141-162 In Terborgh, J. And J. Estes (Eds*.) Trophic Cascades: Predators, Prey and the Changing Dynamics of Nature*. Island Press, Washington, USA.

Terborgh, J. 1988. The Big things that Run the World, A Sequel to E.O. Wilson. *Conservation Biology* 2: 402-403.

Randall, C. 2020. A Rewilding Triumph: Wolves help to Reverse Yellowstone degradation, Guardian, January 25, 2020.

<https://www.theguardian.com/environment/2020/jan/25/yellowstone-wolf-project-25th-anniversary>

Peterson, C. 2020. 25 years after returning to Yellowstone, wolves have helped stabilize the ecosystem. National Geographic, July 10, 2020.

<https://www.nationalgeographic.com/animals/article/yellowstone-wolves-reintroduction-helped-stabilize-ecosystem>