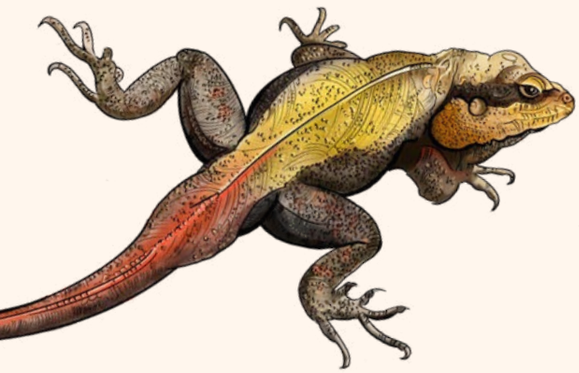
© IISC 2025 - PRIVATE CIRCULATION ONLY









Ecology, Evolution and Everything

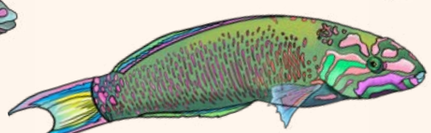












Centre for Ecological Sciences
Indian Institute of Science

© IISC 2025 - PRIVATE CIRCULATION ONLY

I come from a family of scientists (several of whom took research degrees at the Indian Institute of Science), but their genes did not transmit themselves to me, since my own education was resolutely (and narrowly) humanistic. Yet, by a happy accident, I came to have a close association with the IISc, and especially with the Centre for Ecological Sciences, through my collaborative research on environmental history with Madhav Gadgil. I have thus known (and admired) the work of CES since its inception, and developed beneficial friendships with many of its faculty members and doctoral students. It is therefore wonderful to see this collection of elegantly crafted and gorgeously illustrated essays, showcasing the impressive range and depth of the research done by faculty and research scholars in the years since CES's founding. This is an impressive and important book, that deserves a wide readership.

Ramachandra Guha
Author of *Speaking with Nature: The Origins of Indian Environmentalism*

Darwin concluded his *Origin of Species* by reflecting on nature's 'endless forms most beautiful and most wonderful'. *'Ecology, Evolution and Everything'*, a collection of essays by CES faculty, celebrates this diversity of life, showcases the excellent science elucidating the patterns and processes that underpin it, and makes a compelling case for why cherishing and protecting biodiversity is essential, not just for us, but for the generations to follow.

Anne Magurran
Professor, University of St. Andrews, Scotland

This gorgeously illustrated book provides a marvelous and highly readable introduction to India's amazing biodiversity, to the processes that generated it, and to the crucial research being done at the Centre for Ecological Studies to understand this biodiversity and safeguard its future

John J. Wiens
Professor, University of Arizona, Tucson, USA.

Ecology, Evolution and Everything

Scientific stories from IISc's Centre for Ecological Sciences

IISc Press

© IISC 2025 - PRIVATE CIRCULATION ONLY

Concept and Production
Kartik Shanker
Saskya van Nouhuys

Editors
Saskya van Nouhuys
Umesh Srinivasan
Maria Thaker

Primary Artwork
Ravi Jambhekar

Photo Editor
Radha Rangarajan

Design
Reshu Singh

Cover
Reshu Singh with artwork
by Ravi Jambhekar

Additional Artwork
Reshu Singh

Additional Design
Labonie Roy

Copyright © 2025

Centre for Ecological Sciences,
Indian Institute of Science,
Bangalore 560012

IISc Press

SUNDARAM FINANCE
Enduring values. New age thinking.

ISBN 978-81-962307-3-9

Printed by Grafiprint Pvt Ltd.
(Division of WQ Judge Press)
97, Residency Road, Bangalore 560025

Ecology, Evolution and Everything

Scientific stories from IISc's Centre for Ecological Sciences



© IISC 2025 - PRIVATE CIRCULATION ONLY



A mobulid devil ray glides through the tranquil waters of the Indian Ocean
Umeed Mistry | Maldives

Foreword

The Centre for Ecological Sciences was started in 1983 as a Centre for Excellence under the then Ministry of Environment and Forests. It was the first department of ecology in India at the time. Led by its founder, Madhav Gadgil, and stalwarts such as Raghavendra Gadagkar and Raman Sukumar, CES quickly became a leader in the fields of ecology, evolution and behaviour in the country. Forty-two years later, it has blossomed into a vibrant, inclusive and dynamic community of faculty, postdocs, students, researchers and support staff. It seemed like it was time to celebrate this.

But why 42? Fans and followers of Douglas Adams' *A Hitchhiker's Guide to the Galaxy* series will recognise this number as the answer to 'Life, the Universe and Everything', which the supercomputer Deep Thought spits out after 7.5 million years of calculations. While the fandom has speculated widely about the significance of that number (many numerical and cultural reasons have been posited), Adams himself stated that the number was arbitrary.

Given ecologists' love of probability, randomness and noise (and Douglas Adams), we thought that this was as good a year as any to celebrate the things that we love: the tangled and incredible natural world and our efforts to disentangle and understand it. We bring to you a collection of essays on ecology, evolution and behaviour, spanning from individuals to groups, communities and ecosystems, across ecological contexts, and over evolutionary time.

Kartik Shanker
Professor
Centre for Ecological Sciences



Nimish Subramaniam

Contents

Foreword 07

Behaviour

Sexual Selection: Arms, Bling and Drama 10
Kavita Isvaran

The Wondrous World of Animal Societies 16
Raghavendra Gadagkar

Simple Rules, Complex Moves 23
Vishwesha Guttal

Sound and Silence 29
Rohini Balakrishnan



Ecology

Tracking Trees Over Time 36
Raman Sukumar

Eating with the Enemy or Flocking with a Friend? 43
Kartik Shanker

Nature Weaves a Tangled Web 48
Saskya van Nouhuys

Curious Eyes and Nose of a Natural Historian 54
Renee M. Borges

Wildlife, Ecosystems and Climate 61
Sumanta Bagchi



Evolution

Aboard the Indian Ferry 68
Praveen Karanth

Animals Dress to Impress 75
Maria Thaker

A License to Kill 80
Kartik Sunagar

The Elephant in a Nutshell 86
Raman Sukumar



Conservation

The DNA of Rarity 94
Anubhab Khan

Icons of the Ocean 100
Kartik Shanker

The Insidiousness of Invasion 106
Saskya van Nouhuys

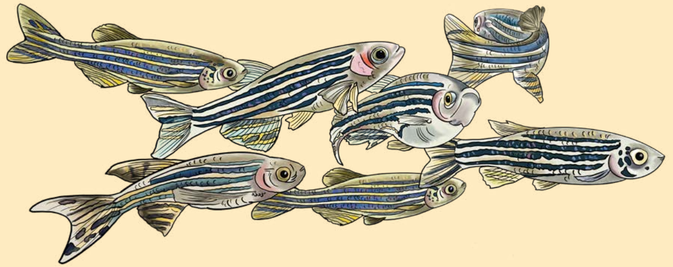
It's Getting Hot Out There 112
Maria Thaker

Biodiversity in the Age of Humans 118
Umesh Srinivasan

Acknowledgements 125
Authors 127
Illustrations 128

© IISC 2025 - PRIVATE CIRCULATION ONLY

© IISC 2025 - PRIVATE CIRCULATION ONLY



Behaviour



© IISC 2025 - PRIVATE CIRCULATION ONLY

Sexual Selection: Arms, Bling and Drama

Kavita Isvaran

Garish plumage, twisting horns and dazzling scales light up the natural world. How do we make sense of these eye-catching features? They do not help animals find food, survive harsh conditions or fight disease. In fact, they attract the attention of predators and parasites, and divert energy away from immune defences. Charles Darwin was the first to elaborate on how competition for mates can produce these puzzling characteristics. He explained that animals that win in the competition for mates produce more offspring. If a trait helps them win and this trait is heritable, it is passed on to offspring and spreads through the population from generation to generation.

In this competition for mates, some characteristics make more sense than others. Weapons, like the horns of beetles and antelopes, the spurs on fowl, and the tusks in walruses and Asian elephants, make sense because we can appreciate how weapons help to defeat rivals and acquire mates. But what about bright feathers, glittering scales,

Male Himalayan monals (Lophophorus impejanus) *exhibit striking iridescent plumage, metallic colouration, and elaborate courtship displays*
Dhritiman Mukherjee | Bhutan

© IISC 2025 - PRIVATE CIRCULATION ONLY

and ritualised movements of many animals? Darwin suggested that such traits increase an individual's reproductive success because mates are attracted to these features. This process of mate choice and its impact on the evolution of conspicuous displays are now well established. However, when it was first proposed, it was very controversial. It seemed to imply that animals, from tiny insects to large mammals, had an aesthetic sense!

It turns out that individuals can gain a lot from being choosy and exercising an aesthetic sense. Males may use displays to advertise the resources on their territories. Displays use up energy and attract not only mates but also competitors. So, it is usually strong males with abundant resources on their territories who display vigorously. By preferring males with high-intensity displays, females benefit from accessing better resources. This increases the number of offspring they can produce or the growth of their offspring. Females, thus, get immediate direct gains from using information in displays when choosing mates. Selecting mates that are healthy rather than parasitised, or those that provide safety from predators, or those that are excellent parents are some of the other direct benefits to females that exercise choice. On the other hand, females may also benefit indirectly, when the males they mate with pass on useful traits to offspring – traits that increase the ability of offspring to fight disease or attract females or escape predators.

A lot of theory, and field and lab experiments have shown, without a doubt, that sexual selection, through direct contests between individuals and through indirect struggles to attract mates, is a powerful evolutionary force. It can result in large bodies and weapons, which help in fights, and conspicuous ornaments and ritualised displays, because they help to attract mates. Males may use not one but many costly displays simultaneously to advertise their quality to competitors or mates. Sexual selection can also affect other aspects of an individual's life that seem unrelated to finding mates, such as their diet, immune system and physiology, and even ageing. In species where males compete fiercely for females, males age much faster and live shorter lives than do females.

"Competition among females is mystifying and isn't easily explained by sexual selection theory, which is built to explain male weapons and displays.



For male blackbuck, striking displays and victories over competitors are key to securing reproductive success
Kalyan Varma | Blackbuck National Park, Velavadar

© IISC 2025 - PRIVATE CIRCULATION ONLY

Male and female peninsular rock agamas (Psammophilus dorsalis), *seen here in their striking breeding colours*
Advait Pai | Rishi Valley School, Andhra Pradesh

Despite the enormous understanding we have gained since Darwin set out his theory of sexual selection, large puzzles remain. At CES, we are successfully addressing several fundamental but poorly understood questions. Historically, males were the focus of research in sexual selection. The dominant thinking is that males compete and females choose. This is because, to reproduce successfully, females need to invest a lot of resources into raising the young and caring for them. Finding food and safety is a larger priority for females than finding many mates. Whereas males, who are usually not involved in the upbringing or caring for their young, achieve success by mating with as many females as possible. However, an avalanche of studies have documented fights and displays by females. Such competition among females is mystifying and isn't easily explained by sexual selection theory, which is built to explain male weapons and displays. Our long-term work on a striking lizard species, the peninsular rock agama, in which sexual selection in males is well-established, shows that female competition is nuanced and cryptic. Females send information to each other using a variety of postures, movements, and colour displays that can be turned on or off. While most interactions are inconspicuous, they can escalate to fierce fights, often more violent than those seen in males! Females also use costly colours and movements to attract males, but deploy these signals very strategically. We are developing theory to explain these differences between female and male competition.





Carefully studying the impact of complex ecological conditions can help to explain puzzling behaviour and overturn seemingly established facts. Long-term work on mating systems in the blackbuck antelope shows that males and females can dramatically change how they find mates depending on ecological conditions. Female blackbuck switch from being attracted to males that defend large open grassy food patches to choosing mates in densely-packed clusters of males that are defending nothing but themselves! Work on crickets has led us to re-examine our assumptions about how predators shape male and female mate-finding strategies. We typically expect the conspicuously calling males to suffer heavy predation and the silently moving females to escape a predator's attention. Careful field experiments on the interaction between sedentary calling males, silent moving females and their predators reveal that, surprisingly, males and females are equally at risk of attack from predators.

The complex landscape that animals live in is further complicated by humans. Our work comparing the displays used during fights and courtship by urban and rural lizards of the same species reveals that urbanisation can affect both the intensity of displays and the underlying physiological mechanisms. Long-term work monitoring lizard morphology reveals that weapons used in the fight for mates are keenly sensitive to climatic conditions that are currently undergoing drastic changes. How sexual selection is likely to alter the bodies and behaviour of animals under the rapidly changing conditions of the Anthropocene is an exciting new and swiftly developing research area. We are working to build a framework to predict how sexual selection operating under anthropogenic impacts will alter the bodies, appearance and behaviour of animals.

The research highlighted here was conducted by Devica Ranade, Shreekant Deodhar, Aravind Sridharan, Gokul Valiyar Parambil, Jayabharathy Ranganathan (Kavita Isvaran's Lab), Viraj Torsekar (Rohini Balakrishnan's Lab), Anuradha Batabyal and Madhura Amdekar (Maria Thaker's Lab).

The Wondrous World of Animal Societies

Raghavendra Gadagkar

© IISC 2025 - PRIVATE CIRCULATION ONLY

Every animal is a marvel of nature, but social animals are even more so. Many animal species live in social groupings and often cannot survive otherwise. Schools of fish, shivers of sharks, flocks of birds, gaggle of geese, mobs of crows, packs of dogs, wolves, and hyenas, herds of deer, bison, and elephants, prides of lions, troops of monkeys, chimpanzees, and gorillas, and of course, human societies all come to mind. Social life needs special adaptations. Animals must find each other, stay together, tolerate each other, communicate to coordinate their movements, actions, foraging and predation efforts, defend themselves, share resources amicably, breed together, and sometimes migrate long distances.

However, it is a mistake to think that complex social life is restricted to vertebrates, requiring large brains and advanced nervous systems. Spectacular as they are, vertebrate societies are in many ways simpler and present less of an evolutionary puzzle than the remarkable societies of insects such as ants, bees, wasps, and termites. In many insect societies, social integration and communication have reached far greater sophistication. For example, a single colony of some ant species contains over a million individuals, nearly all of whom, barring just one or a few fertile queens, are sterile workers altruistically devoting their entire lives to the welfare of the colony without producing any offspring of their own. Incidentally, the queens and all workers are female, the males do not participate in social life (except in termites); they merely mate and die! These insect societies build architecturally complex nests with precise climate control and navigate their environment using terrestrial and celestial cues. Perhaps even more impressively, they continuously monitor every twist and turn in their meandering foraging paths, memorise landmarks, and compute the shortest route back home. If that is not impressive enough, consider this: upon returning to the nest, honey bee foragers will dance to communicate the direction and distance to the food source they have discovered, so that naïve nestmates can then go there on their own and retrieve the pollen or nectar as the case might be.

The Asian giant honey bee (Apis dorsata), *builds massive open-air colonies that can house up to 100,000 individuals*
Thresiamma Varghese | Indian Institute of Science Campus, Bangalore





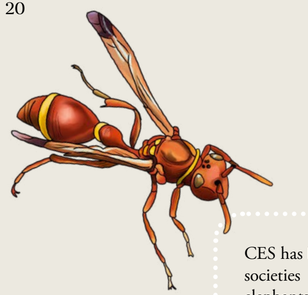
© IISC 2025 - PRIVATE CIRCULATION ONLY

A pair of Asian weaver ants (Oecophylla smaragdina) *transporting their prey, a female jumping spider* (Hyllus semicupreus)
Jithesh Pai | Kavoor, Mangalore

Insect societies represent only some 2% of the one million species of insects described so far. Yet, they are among Earth's most evolutionarily successful and ecologically dominant species, estimated to comprise up to three-quarters of the total animal biomass in some tropical forests. Our planet is believed to contain some 20 quadrillion ants – that's about 12 megatons of dry carbon, more than that of all wild birds and mammals combined. And, if you are still not impressed, the biomass of all ants is about 20% of all humans put together! And the biomass of termites in the soil may far exceed even that of ants.

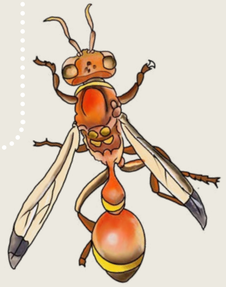
Insect societies present at least two paradoxes. First, how does natural selection favour the evolution of altruistic sterile workers who obtain no personal Darwinian fitness? This prompted a significant revision of the traditional Darwinian understanding of natural selection, leading to the realisation that producing one's offspring is but one way of garnering evolutionary fitness. Aiding relatives who also share genes with the altruist is another. Such 'kin selection' is at least part of the answer to the riddle of altruism. Second, how do insects, with their tiny brains, achieve such complex societal accomplishments? There seem to be at least two complementary clues to this riddle. One clue is the increasing appreciation that big brains are unnecessary – the study of 'cognition with small brains' is the new kid on the block. The other clue is that cognition itself may be unnecessary – complex social behaviour can result without the conventional intelligence of individual members but through decentralised self-organisation with individuals following simple local rules that result in the emergence of complexity.

> ***Complex social behaviour can result without the conventional intelligence of individual members but through decentralised self-organisation with individuals following simple local rules that result in the emergence of complexity.***



CES has been at the forefront of studying animal societies such as those of birds, blackbuck, elephants, ants, bees, wasps and termites and solving the evolutionary riddles they pose. We have spent decades understanding the fascinating insect society of the locally abundant Indian paper wasp, *Ropalidia marginata*. The choice of this species has been propitious. *R. marginata* appears to be the missing link between primitive insect societies such as those of many wasps and bees and the more advanced societies of honey bees, ants and termites. Primitively eusocial species have small colonies, usually with fewer than a hundred individuals. Their queens and workers are morphologically indistinguishable, and queens generally regulate the activities of their workers and suppress their reproduction through physical aggression. Advanced insect societies on the other hand have large colonies with tens of thousands or even a million individuals; queens and workers are morphologically differentiated and queens regulate worker reproduction by means of pheromones. *R. marginata* colonies consist of a single fertile queen and often no more than 20 to 30 sterile workers. Remarkably, the queen is indistinguishable from her workers by her appearance and size and yet maintains complete reproductive monopoly and she does so not by aggression but by means of pheromones. However, the queen is periodically overthrown by one of her workers who in turn is overthrown by another. Such periodic queen succession is surprisingly peaceful with no overt conflict. Indeed, there are several heir-designates lined up in a reproductive queue. Our research has shown that rather than the absence of conflict it is efficient conflict management that results in an outwardly peaceful and highly successful society.

The research on social paper wasps highlighted here was conducted by Prof. Gadagkar, his students and postdocs.



© IISC 2025 - PRIVATE CIRCULATION ONLY



In Indian paper wasp (Ropalidia marginata) *colonies, queens come and go without a fight, passing power peacefully through a queue of successors*



© IISC 2025 - PRIVATE CIRCULATION ONLY

Blackbuck herds rely on collective vigilance and their remarkable speed, moving together as one to confuse and evade predators
Kalyan Varma | Blackbuck National Park, Velavadar

Simple Rules, Complex Moves

Vishwesha Guttal

From swarming locusts to flocks of birds swirling in mesmerising murmurations to schools of fish moving in synchrony, collective animal movement is one of nature's most striking displays of self-organisation. These spectacular movements need not arise from a single leader or centralised control but from local interactions among organisms following simple rules. This phenomenon exemplifies what is referred to as an emergent property, where group-level patterns arise from the behaviours and interactions of individuals.

The study of collective movement has benefited immensely from insights from a variety of disciplines outside of traditional biology, in particular the fields of physics, mathematics and computer science. For instance, the field of statistical physics has helped explain the role of stochasticity (random fluctuations) in flocking behaviour, while computer vision techniques have played a crucial role in developing state-of-the-art technology for experiments and data analysis. Taken together, this research has shown that simple behavioural rules – such as alignment with neighbours' direction of movement, attraction towards the group, and repulsion to avoid collisions – with a bit of stochasticity to top it up, can lead to remarkably intricate and adaptive movement patterns.

Collective movement confers significant benefits to the individuals participating in such groups. One key advantage is reduced predation risk, exemplified by the confusion effect, where predators struggle to target an individual in a dense, fast-moving group. Additionally, collective motion facilitates rapid information transfer, allowing individuals to respond quickly to threats or changes in the environment. Another critical advantage is collective decision-making, where group members can pool information and reach more accurate decisions about navigation routes, foraging sites, or resting locations. Thus, individual-level interactions can enhance survival and efficiency at the group level.

Understanding collective movement is not merely an academic pursuit; it has implications for conservation, robotics, and even human crowd dynamics. Studying how animals move collectively may need to be accounted for while formulating wildlife conservation strategies. It also finds applications in designing autonomous robot swarms that mimic biological coordination to perform tasks efficiently.

India, with its rich biodiversity and diverse ecosystems, hosts some of the most fascinating examples of collective movement. One such beautiful example is the synchronised movement of blackbuck *(Antilope cervicapra)* herds. These herds are known for their highly coordinated escape responses when faced with predators. Their ability to execute rapid, synchronised turns while running at high speeds helps them evade threats.

Another remarkable case is the Amur falcon *(Falco amurensis)* migration, one of the largest avian migrations passing through India. These small birds of prey travel in massive flocks from breeding grounds in East Asia to wintering sites in Africa, stopping en route in Northeast India.

India also witnesses spectacular insect migrations: one fascinating example is the mass aerial movement of dragonflies which migrate thousands of kilometres, from India to Africa, crossing the Indian Ocean. Studying such movements provides insights into how small insects without high cognitive abilities still manage long-distance navigation through environmental cues.

© IISC 2025 - PRIVATE CIRCULATION ONLY

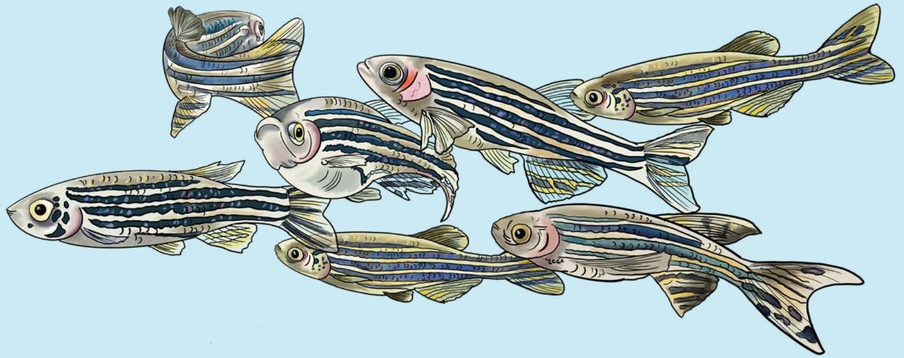


Amur falcons (Falco amurensis) *migrate in massive flocks, coordinating their flight, roosting, and feeding along the way*
Dhritiman Mukherjee | Ntangki National Park, Nagaland

©IISC 2025 - PRIVATE CIRCULATION ONLY

CES studies have revealed how intrinsic noise – the inherently random nature of interactions among fish when in groups – can paradoxically enhance coordination in fish schools.

Reef fish such as silversides, surgeonfish, and fusiliers show striking examples of coordinated movement
Dhritiman Mukherjee | Andaman and Nicobar Islands



Research at CES has significantly advanced our understanding of collective movement across diverse taxonomic groups, integrating empirical observations, computational models, and novel techniques for tracking individuals. CES studies have revealed how intrinsic noise – the inherently random nature of interactions among fish when in groups – can paradoxically enhance coordination in fish schools. Our research has shown that fish may be using simpler behavioural rules than those suggested by the models from physics and mathematics, which already substantially simplify the complex real world phenomena!

Our long-term research on blackbuck has revealed how habitat structure and resource distribution influence group formation and vigilance against predators, reinforcing the idea that ecological factors shape collective behaviour. CES research suggests that mating strategies such as lekking behaviour – where competition for mates results in the formation of relatively closely packed territories where multiple males display to attract females – can be understood through principles of self-organisation, linking reproductive strategies with movement dynamics. Our recent work has gathered high-resolution drone-based videos of blackbuck herds escaping predatory threats, and of males and females interacting in a lek. These videos have the potential to reveal to the nature of interactions between individuals on fine spatio-temporal scales.

With a strong interdisciplinary approach, CES researchers combine field experiments, high-speed imaging, and computational modelling to answer fundamental questions about collective movement in a wide variety of species, from mosquito swarms to fish schools to blackbuck and elephant herds. Our research not only deepens our understanding of how animals coordinate their movement but, potentially, has broader applications in ecology, conservation, and bio-inspired robotics.

The research highlighted here was conducted by Jitesh Jhawar, Akanksha Rathore, Jaideep Joshi, Arshed Nabeel, Vivek Jadhav, Cassandre Aimon, Jahanvi Tiwari (Vishwesha Guttal's Lab) and Kavita Isvaran.

© IISC 2025 - PRIVATE CIRCULATION ONLY

Sound and Silence

Rohini Balakrishnan



Dawn and dusk animal choruses are a striking and universal part of our sensory world, no matter where we live on earth. Birds at dawn, cicadas and grasshoppers in the day, insects and frogs at night, are all calling out loud: but why? Most of these calls are made by males, either to defend their territories or to attract females from afar to mate with.

So how does a solitary little male cricket manage to find a mate in the darkness of night? He sings out loud, a song, by rubbing his wings together. His unique melody proclaims his species identity, and often his size and state of health. Females of his species are tuned in to his call, pitch and rhythm, and will move towards his song to find him. But a male isn't alone in trying to attract females. Other males of his species around him are singing too, competing for females. So how does a female decide whom to move toward? She uses a simple rule: just turn and walk towards whoever is loudest. The louder the male the more likely he is to get females and the longer they will mate with him, increasing his chances of paternity. But being loud needs energy and there's a limit to how loud a male can get. If he is not in good enough body condition or has not eaten enough, he becomes the loser in the competition.

Male tree crickets turn leaves into tools by biting a hole to create a natural baffle and singing through them to amplify their calls
Ananda Shikhara Bhat | Bangalore, Karnataka

Tree crickets have found an innovative solution to deal with this problem: a tool, an acoustic amplifier called a baffle, made out of leaves. Researchers in CES have found that they bite a hole in a leaf and sing through it, which amplifies their songs as much as three-fold. In India, we have four species of tree crickets of the genus *Oecanthus*. Only one of these, *Oecanthus henryi*, makes baffles in leaves to amplify their songs. But we find that not every male *O. henryi* makes a baffle. Smaller and quieter males, typically the losers in the competition, are more likely to employ these tools, which make them sound much louder than they are, drowning out the competition and attracting females. So losers can become winners by using these acoustic amplifiers!

But it's not all about being loud. Crickets, and many other animals too, can use the strategy of remaining silent, close to another singing male, and intercepting females that approach the singer, obtaining matings on the sly. This sneaker or satellite strategy is used by cricket males to get 'cheap' matings without themselves expending energy in the costly business of singing.

© IISC 2025 - PRIVATE CIRCULATION ONLY



False leaf bushcrickets are discreet – females respond to male chirps with body tremors on branches, which the males track as vibrations
Saravanakumar | Kadari, Karnataka

“But it's not all about being loud. Crickets, and many other animals too, can use the strategy of remaining silent, close to another singing male, and intercepting females that approach the singer, obtaining matings on the sly.

© IISC 2025 - PRIVATE CIRCULATION ONLY

For crickets, singing to attract mates is risky – the same chirps that draw females can also lead predators like bats to the source

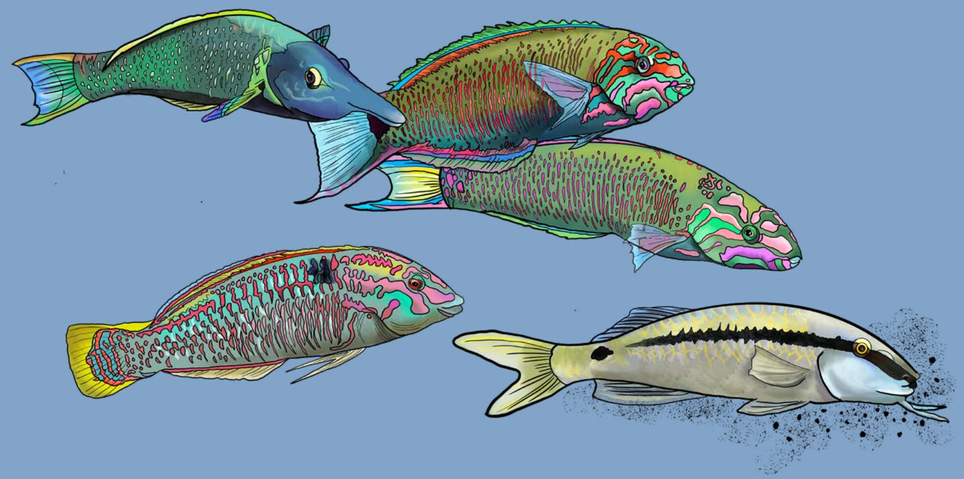






The cost of singing isn't just in exercising all those muscles and using up energy. Singing also makes a male conspicuous and attracts the attention of unwanted and dangerous eavesdroppers, including predators like bats, who may use the sounds to approach and capture the singers. But how can singers minimise their risks? They could hide deep in the vegetation and sing, making it difficult for predators to find them or they can team up and sing together! Males of the long-legged, chirping bushcricket *Mecopoda*, common across peninsular India, seem to use this strategy. They aggregate and sing in chorus, which decreases their chances of being picked up for dinner by a hungry bat, who finds it hard to locate one singer among many. On the other hand, false-leaf bushcrickets, *Onomarchus uninotatus,* from the tree canopies of the Western Ghats, have a different trick up their sleeves. Females reply to male chirps by tremulating, shaking the body with their feet on the branch. This sends a silent message to the male via vibrations in the branch: a song-and-dance duet! He then stops singing and tracks the vibrations to find her, safe from any lurking bat.

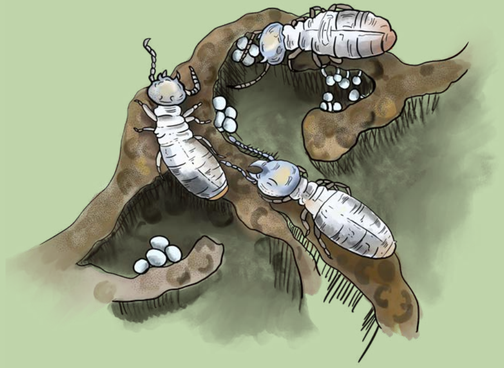
The research highlighted here was conducted by Natasha Mhatre, Sapna Metrani, Rittik Deb, Viraj Torsekar, Mohammed Aamir Sadiq, H Raghuram, Harish Prakash, Bittu Kaveri Rajaraman, Aswathy Nair and Kasturi Saha (Rohini Balakrishnan's Lab).



© IISC 2025 - PRIVATE CIRCULATION ONLY



Ecology



Tracking Trees Over Time

Raman Sukumar



Tropical rainforests have long been considered the holy grail of ecological studies because of the high diversity of plant and animal species they harbour. They have been at the centre of long-standing questions about latitudinal diversity gradients, where the species richness of most taxa increases from boreal and temperate to tropical regions. Studies on rainforests have sparked theoretical questions about how so many plant species are able to coexist in a small space.

In the 1980s, the Smithsonian Institution set up the world's first 50-hectare (ha) forest plot on Barro Colorado Island (BCI) in Gatun Lake, a part of the Panama Canal. This would become, over the next few decades, the most studied forest in the world. Some important insights in ecology, such as Stephen Hubbell's neutral theory of community ecology, the excessive presence of rare tree species, and the metabolic theory of allometry in tropical trees, among others, have been tested based on research at this site. Incidentally, after more than four decades of research, Hubbell admits that we are no closer to answering the question of how more than 300 species of trees and shrubs co-exist in the BCI's 50-ha plot.

Though tropical dry forests comprise a respectable 40% of all tropical vegetation, they have been largely neglected by ecologists, especially from a theoretical perspective. True, the dynamics of savanna-woodlands, such as the Serengeti, have been cast within conceptual models, including 'tipping points' and alternative stable states. For the most part, however, these studies have had an applied focus on how fire and large mammal populations are major drivers of vegetation dynamics. Tropical dry forests of the Western Ghats can thus be expected to have been structured by the vagaries of climate and the voracious feeding behaviour of elephants and other large mammals they host.

The third 50-ha long-term forest research plot was established in 1988 in India, in the central part of Mudumalai National Park, Tamil Nadu, within a seasonally dry forest area free from direct human influences. Mudumalai is much drier than the earlier two plot locations, in Panama and in Malaysia. Eventually, this initiative would lead to a global network of 84 large-scale forest plots, monitoring 7 million trees comprising 12,000 species across 29 countries, which have provided broad, general insights into forest dynamics.

© IISC 2025 - PRIVATE CIRCULATION ONLY

Mudumalai in the Nilgiris hosts a wide range of habitat types from tropical dry forests to tropical semi-evergreen forests
R Sukumar | Mudumalai National Park, Tamil Nadu

Tropical dry forests of the Western Ghats can thus be expected to have been structured by the vagaries of climate and the voracious feeding behaviour of elephants and other large mammals they host.



© IISC 2025 - PRIVATE CIRCULATION ONLY

Large trees are able to escape the frequent fires that occur in this tropical dry forest
R Sukumar | Mudumalai National Park, Tamil Nadu

When first mapped during 1988-89, the Mudumalai 50-ha plot had 72 tree species of nearly 26,000 woody plants greater than 1 cm diameter (at 1.3m height). Four canopy species – *Lagerstroemia macrocarpa, Terminalia crenulata, Anogeissus latifolia* and *Tectona grandis* – made up nearly half the trees enumerated in the plot, though the understorey *Kydia calycina*, a favourite of the elephant, had the honour of being the most abundant tree, while *Helicteres isora* dominated the shrub layer. The thorny bamboo *Bambusa arundinacea* began mass flowering in 1991, dispersed its seed and soon died out in the plot.

It soon became apparent that this forest experienced a rapid turnover among the younger plants. Forest fires burned the young trees regularly, while elephants stripped the bark and pushed over their staple browse species. The population of woody plants soon crashed to about 15,000 individuals. The redeeming feature was that the larger trees seemed to persist for a very long time! In fact, the annual growth rings of teak *(Tectona grandis)* trees were up to 300 years old and, in one case, 400 years old. Once trees reached 30 cm in diameter, they suffered only 0.5% mortality each year. Even when southern India experienced a prolonged drought from 2000 to 2004, the death rate of these large trees did not increase alarmingly.

As we make progress with the full enumeration of the plot during 2024-25, my thoughts return to 1987, when Steve Hubbell, a pioneer in advocating for large-scale tropical forest plots, visited Mudumalai. Seeing a forest with many large trees but an understorey of grasses, he concluded that this forest would become a grassland within 25 years. I countered that this forest had been around for hundreds of years and there was no reason to believe the trees would now rapidly vanish.

Since 2005, there has been an upswing in the number of recruits, despite a fire in 2010, and the total tree community comprising 90 species has already surpassed the 100,000 mark. Although birds, monkeys, deer and elephants disperse fruits and their seeds, the vast majority of recruits have sprung from coppices. The above-ground carbon stocks (the new mantra in most conversations on forests in the era of climate change) have also increased over the past four decades, though somewhat unevenly, at rates comparable to those in the Amazon, which is not bad at all for a species-poor tropical dry forest!

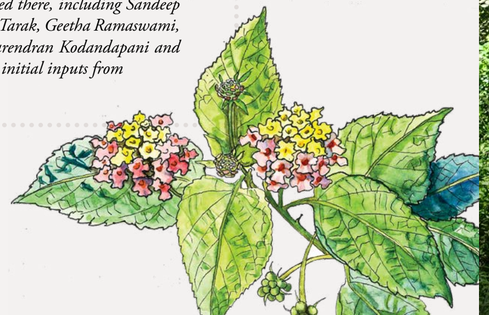
© IISC 2025 - PRIVATE CIRCULATION ONLY

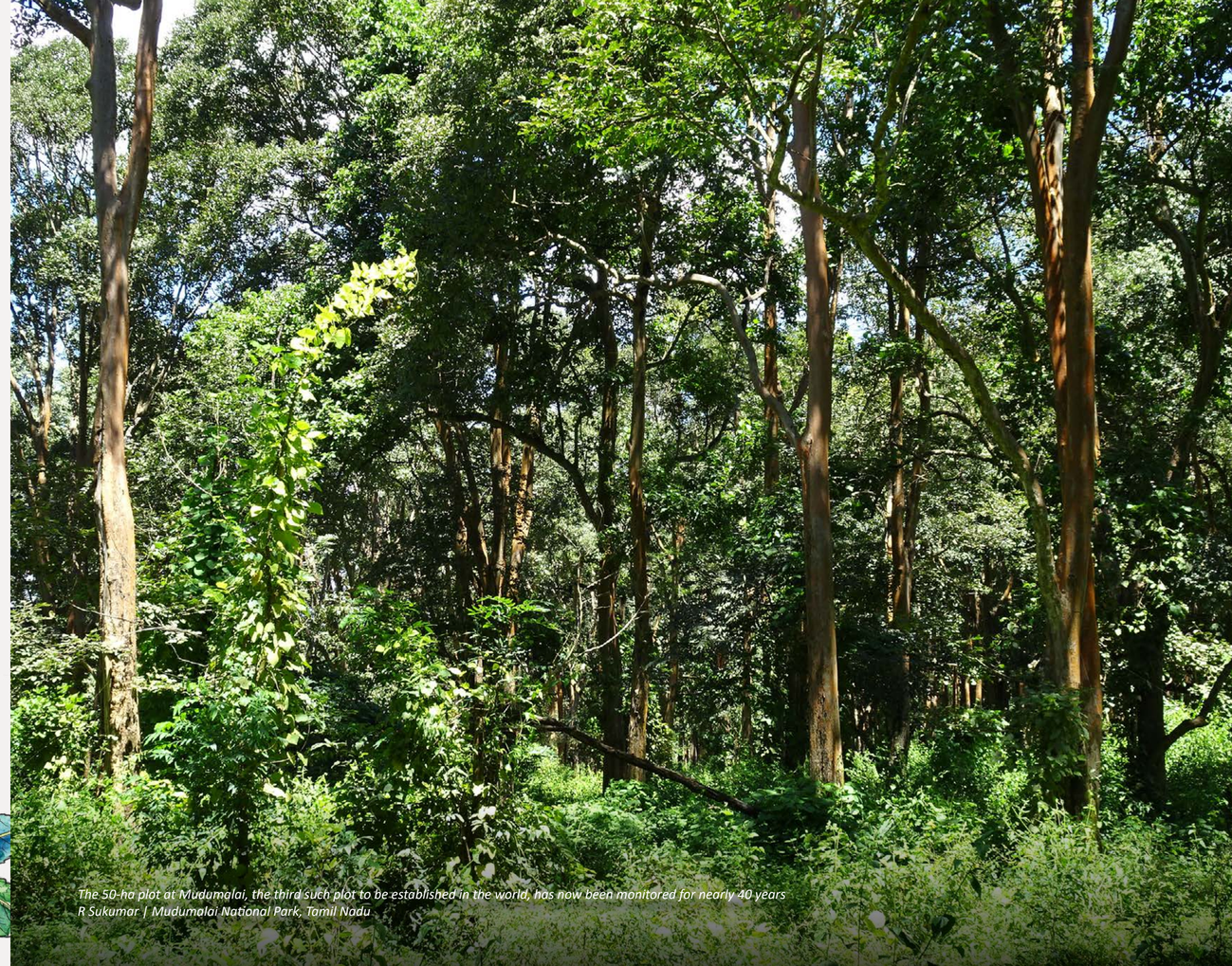
Monitoring the 50-ha plot for nearly four decades involves the annual grind of revisiting the plot and recording which trees have died, the cause of their death, and the number and identity of 'recruits' or plants that have crossed the 1 cm dbh (diameter at 1.3 m height) threshold. We had set up the plot in a location that received about 1250 mm of rainfall on average per year. It turned out that this central region of Mudumalai also experienced the highest fire frequencies due to the optimal conditions for biomass (fuel for fires) production and desiccation (flammability). The eastern region of Mudumalai was drier but produced too little fuel, while the western region produced more fuel, but was too wet to burn. We used statistical models to show that the dynamics of this tropical dry forest were regulated mainly by environmental fluctuations, in particular, rainfall, temperature and fire.

There have been other surprises as well. During the prolonged drought, the tree species that were more prone to dying were not the shallow-rooted ones, but the deep-rooted ones, such as *Terminalia crenulata,* which is otherwise a very hardy species, because they ran out of water from the deeper layers of the soil.

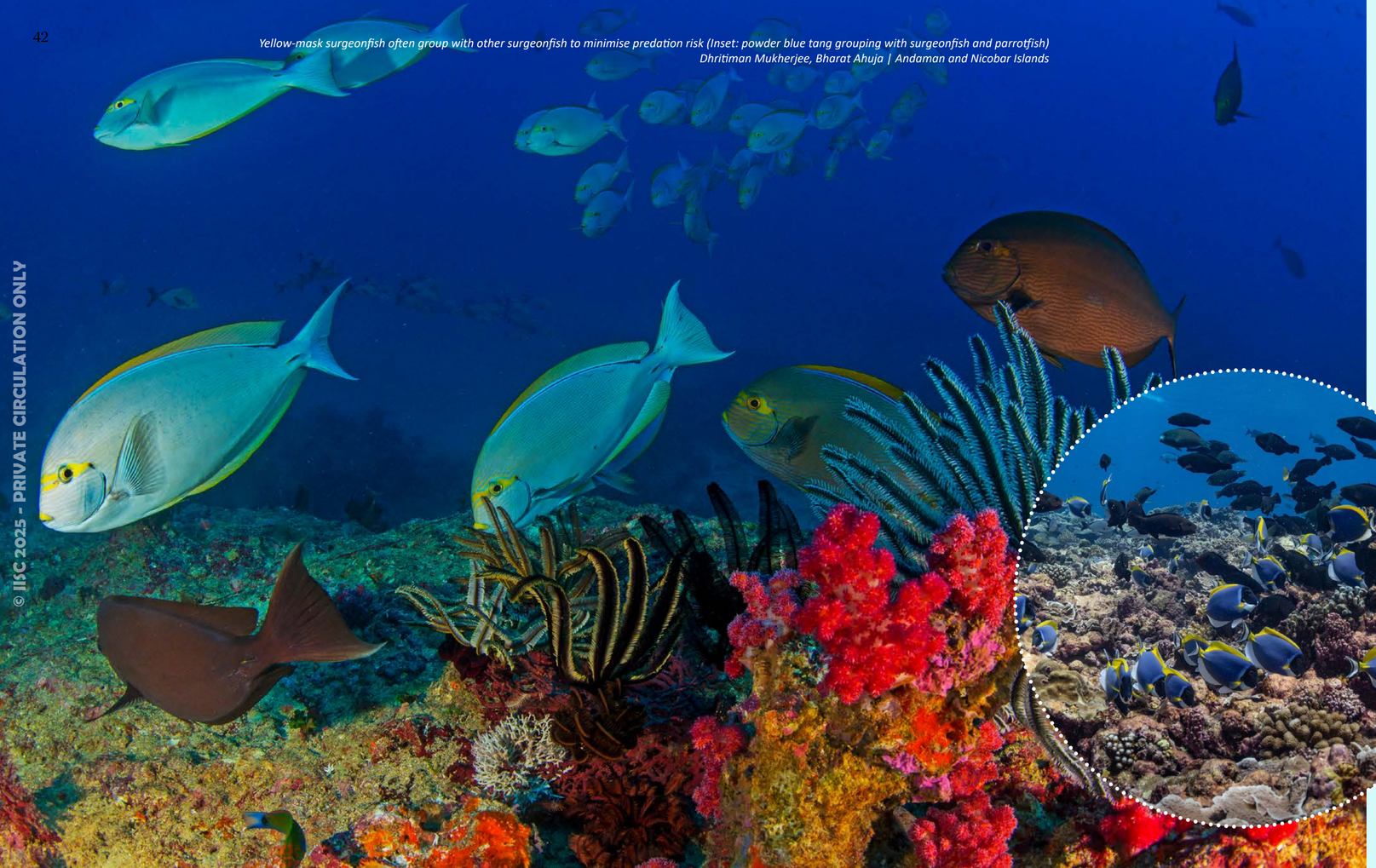
We were careful to set up the plot in an area relatively free of the unwanted, thorny invasive shrub *Lantana camara,* described as among the worst invasives globally. Following the great drought and a large fire event, this invasive plant began to spread rapidly when good rains returned by 2005, soon outcompeting the grasses not only in the 50-ha plot but across a large swathe of forests in the Western Ghats. Clearly, this was a regional-scale phenomenon in which drought, fire and perhaps the increasing carbon dioxide in the Earth's atmosphere provided favourable conditions for this woody invasive to grow and spread.

The research highlighted was carried out by a large team, not all of whom can be named here. This mammoth task has been sustained by dedicated botanists and staff who have stayed with programme through the years (H.S. Suresh, H.S. Dattaraja, C.M. Bharanaiah, N. Arjunan), and with the assistance of a large number of Kuruba field assistants at Mudumalai. Many students and researchers have worked there, including Sandeep Pulla, Rutuja Chitra-Tarak, Geetha Ramaswami, Nandita Mondal, Narendran Kodandapani and Soumya Prasad, with initial inputs from N.V. Joshi.





The 50-ha plot at Mudumalai, the third such plot to be established in the world, has now been monitored for nearly 40 years
R Sukumar | Mudumalai National Park, Tamil Nadu



Yellow-mask surgeonfish often group with other surgeonfish to minimise predation risk (Inset: powder blue tang grouping with surgeonfish and parrotfish)
Dhritiman Mukherjee, Bharat Ahuja | Andaman and Nicobar Islands

© IISC 2025 - PRIVATE CIRCULATION ONLY

Eating with the Enemy or Flocking with a Friend?

Kartik Shanker

Animal groups are fascinating and awe-inspiring sights. Vast herds of wildebeest in African savannahs, flocks of flamingos in coastal wetlands, schools of surgeonfish in tropical coral reefs and many others. Many species live in groups where members of the same species come together for foraging, mating, warmth or simply to increase their chance of survival against predators. But often, these groups comprise multiple species. Wildebeest may be joined by zebras or one or more of Africa's many antelopes. Flamingos are often surrounded by other waterbirds. And different species of surgeonfish may group together, often with parrotfish and other species.

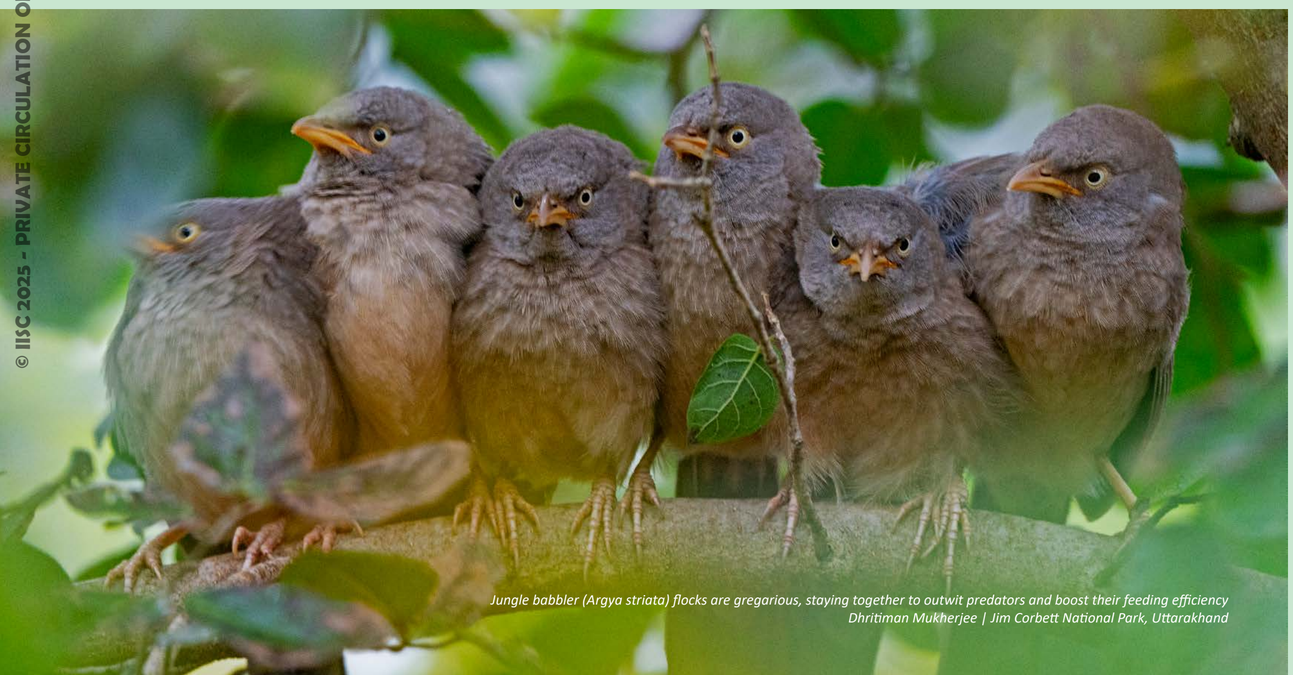
But why do these species associate with each other? What benefits might they gain? Broadly, ecologists agree that mixed species groups (MSGs) form for two main reasons: protection from predators and better access to food. Protection from predators can come about in various ways in both single and mixed species groups. One of these is called the dilution effect: simply put, when in a group, the chance of any individual being targeted by a predator becomes lower – their chance of being killed is 'diluted'. Other ways to gain protection include joining aggressive or group-living species that can detect predators or chase them away.

These antipredator gains may be offset by the cost of competition for food in large groups or even the greater chance of being detected by predators. Interestingly, MSGs can also include species that are otherwise solitary – these species can determine when they want to be in groups to gain benefits and be solitary at other times. When species that are similar associate together for similar benefits, we call them supplementary groups.

The other major benefit of mixed-species grouping is gaining food. Animals may benefit by copying food locations, eating prey that other animals disturb as they move, or by stealing food from others. For example, sallying bird species like drongos and monarchs (those that catch prey in mid-flight) often follow birds that glean on the bark and off leaves to catch the prey they flush out. Similarly, goatfish search for food on sandy substrates and stir up various invertebrates that wrasses and others feed on. Such associations result in complementary benefits.

Many mammals form MSGs, particularly ungulates in open savannahs, primates and cetaceans. MSGs of birds are common in both temperate and tropical forests, and are the most diverse, with groups comprising a few to over 70 species. Fish show a diverse set of associations such as shoaling groups that form for anti-predation benefits, attendant groups wherein some fish follow others for food, and joint hunting groups in which different predators hunt together. Less is known about invertebrates, but MSGs have been observed in butterflies (while mud-puddling), spiders and ants.

There are many noteworthy cross-taxon alliances in nature as well. In Norse mythology, wolves and ravens are immortalised as the god Odin's companions. In the myth, the ravens scouted ahead to find prey that the wolves could bring down, providing them with a carcass to scavenge on. Today, ravens are known to signal the presence of carcasses to wolves and other scavengers and even to form relationships with wolf packs, interacting and playing with the pups.



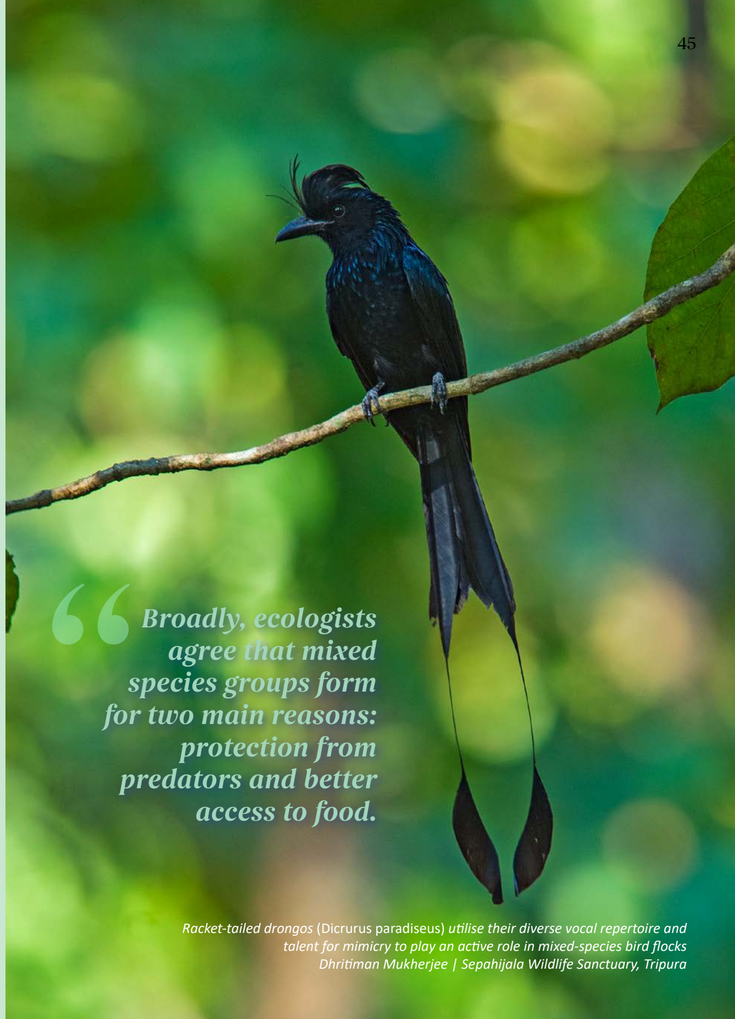
Jungle babbler (Argya striata) flocks are gregarious, staying together to outwit predators and boost their feeding efficiency
Dhritiman Mukherjee | Jim Corbett National Park, Uttarakhand

Some animals can manipulate others into providing benefits. Drongos, which are amongst the champion mimics of the bird world, are known for faking alarm calls to make other birds drop their prey, which they then steal, an interaction known as kleptoparasitism. Fork-tailed drongos do this to meerkats and other birds in Africa, while racket-tailed drongos ply their trade across India, southern China and southeast Asia.

Other fascinating associations occur between unlikely pairings. On Great Nicobar Island, treeshrews are joined by greater racket–tailed drongos as well as a sparrowhawk, which would typically be a potential predator, but in the group, they feed on flushed prey instead. At coral reefs, moray eels and groupers have forged a hunting partnership where the eel is able to enter crevices to catch fish, and the grouper gets those that escape. Groupers are known to signal to moray eels by shaking their head to initiate a hunt.

Humans participate in MSGs as well. In Africa, they follow honeyguides (a group of indicator birds) to harvest honey, with the bird benefitting by gaining access to larvae, wax and honeycombs that the hunters leave behind. Dolphins and humans have been known to fish cooperatively in some parts of the world. Some scientists have even suggested that the association between Neanderthals and wolves may have been an MSG, if the wolves were a willing participant (and not domesticated by then).

© IISC 2025 - PRIVATE CIRCULATION ONLY



"Broadly, ecologists agree that mixed species groups form for two main reasons: protection from predators and better access to food.

Racket-tailed drongos (Dicrurus paradiseus) *utilise their diverse vocal repertoire and talent for mimicry to play an active role in mixed-species bird flocks*
Dhritiman Mukherjee | Sepahijala Wildlife Sanctuary, Tripura

© IISC 2025 - PRIVATE CIRCULATION ONLY

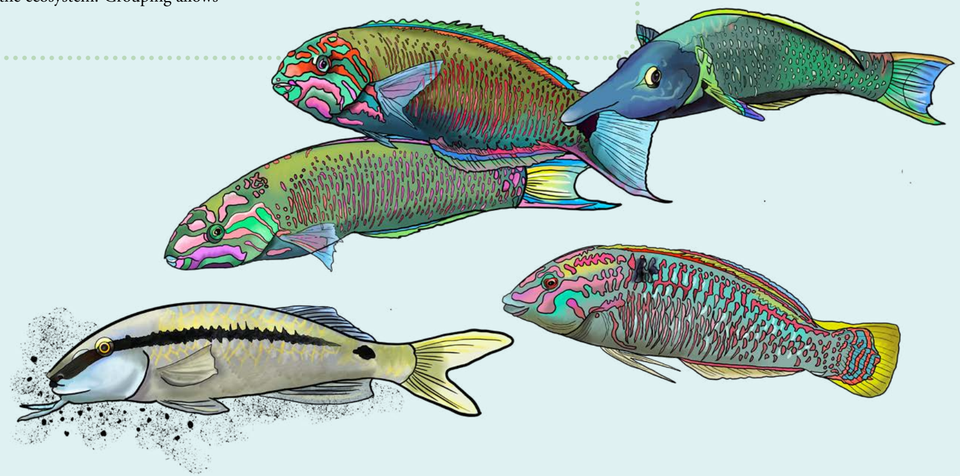
CES researchers have been studying mixed-species flocks of birds in the Western Ghats, Western Himalaya and Northeast India. We find that birds that form single-species groups (like babblers, fulvettas and warblers) are central to grouping as they provide important benefits to other participants. Moreover, species may exercise more choice when joining smaller groups, whereas larger groups tend to be more akin to random assemblages.

Mixed species flock in the Western Ghats
Maanasa Ganesh, for Current Conservation

In Northeast India, mixed-species flocks form in response to resource scarcity, suggesting an important ecological role for this behaviour. In some of these bird MSGs, individuals of one species often associate with the same individual of another, as in the case of rusty-fronted barwings and black-crowned scimitar babblers. Participating in MSGs may also help them survive – unlike others, grouping species do not suffer reduced survival rates even in the face of forest degradation.

Our research on reef fish groups in the Lakshadweep and Andamans Islands suggests an important role for herbivore groups, comprising surgeonfish and parrotfish groups; they facilitate reef recovery after bleaching by grazing on algae and preventing them from taking over the ecosystem. Grouping allows these species to forage effectively in these habitats, and perhaps overcome territorial damselfish which actually farm algae; if left unchecked, this could exacerbate algal domination of the reef. Thus, MSGs are not just fascinating phenomena, but can have consequences for both species survival and ecosystem health.

The research highlighted here was carried out by Hari Sridhar, Priti Bangal, Anne Theo, Bharat Ahuja, Priyanka Hari Haran, Geetika Aggarwal and Kanika Aggarwal (Kartik Shanker's Lab) Umesh Srinivasan (himself), Akshay Bharadwaj (Umesh's Lab) and Samira Agnihotri (Rohini Balakrishnan's Lab).



Nature Weaves a Tangled Web

Saskya van Nouhuys

© IISC 2025 - PRIVATE CIRCULATION ONLY



Individuals consume resources to fuel their activities, grow and reproduce. Many organisms on earth, that is, the plants and algae, use energy from the sun and carbon from CO_2 in the air or water for this. In so doing, they provide organic matter that the rest of us use for energy and as the building blocks for our own bodies. Ecological communities are made up of these primary producers, herbivores and pathogens that eat them live, and detritivores that eat them once they have died. Then there are carnivores which eat the detritivores, herbivores, and one another. The survival and abundance of species at each trophic level depend in part on how much resource they acquire, as well as how much they are preyed upon by species at other trophic levels. This leads to an interconnectedness of species, even among those that are not directly connected to each other trophically in the food web.

If we look around in natural terrestrial environments, there are a lot of plants. Except under extreme physical conditions of aridity, temperature, or darkness, the world is mostly green. Plants are an abundant resource for herbivores, both invertebrates as well as vertebrates. And those herbivores are resources for predators. In fact, one of the reasons the world is so green might be that predators keep the herbivore populations at bay, which means that herbivores cannot increase uncontrollably in numbers and eat all the plants on earth. However, despite predators feeding on them, herbivores play a large role in controlling plant biomass and the species composition of plant communities. Thus, plants must defend themselves against herbivores. They have physical defences such as thorns and hairs, and chemical defences that make them distasteful, difficult to digest or poisonous.

Because predators consume a significant number of herbivores, the welfare of predators is advantageous to plants. There are many fascinating examples of plants facilitating predators as a form of indirect defence. For instance, plants emit volatile chemical odours when insects break cells while eating them. These odours are attractive to parasitoids, which are wasps or flies that lay their eggs in other insects. The offspring grow up feeding on the host insect, eventually killing it.

A parasitoid of fig-pollinating wasps finds its hosts in a Ficus hispida *fig*
Nikhil More | Indian Institute of Science Campus, Bangalore

© IISC 2025 - PRIVATE CIRCULATION ONLY

In their final larval stages, some Papilio caterpillars mimic small snakes
Anaswar P | Indian Institute of Science Campus, Bangalore



In early larval stages, some Papilio caterpillars resemble bird droppings
Anaswar P | Indian Institute of Science Campus, Bangalore



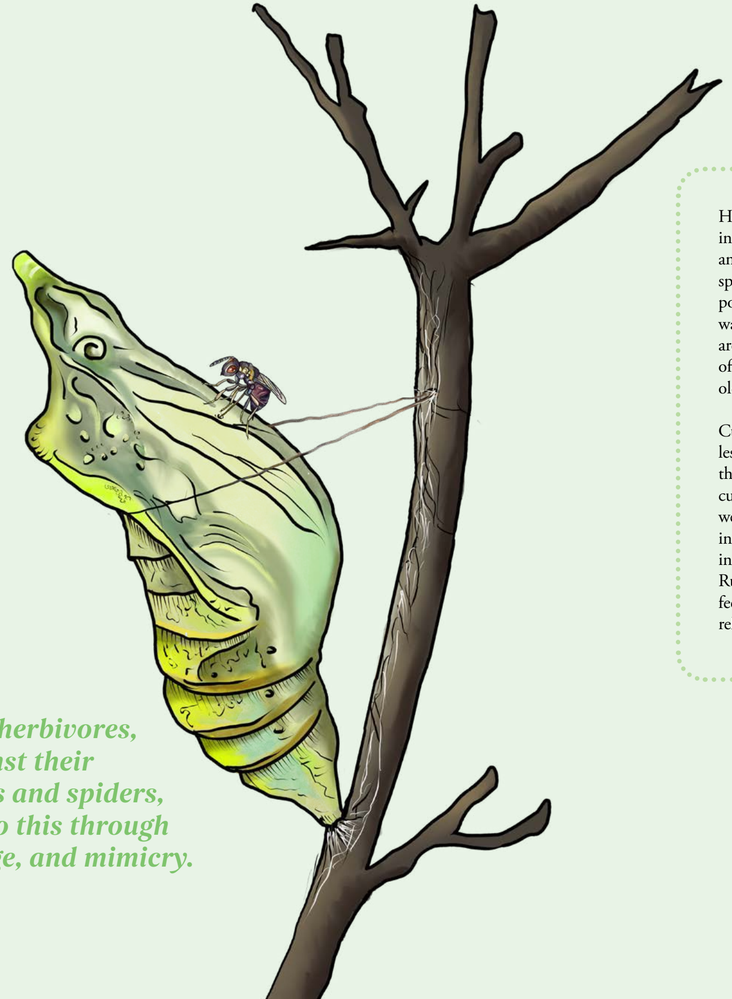
The larvae of the common lime (Papilio demoleus) *exhibit two forms of mimicry: first resembling bird droppings and later a snake*
Karthikeyan Srinivasan | Doresanipalya Forest Research Station, Bangalore

There are parasitoid species that use most, if not all, herbivorous insect species, which makes them a very important type of predator. The odour of a herbivore-damaged plant can be generalised in that it attracts different parasitoids, regardless of which herbivore is eating the plant. In some cases, the volatile odours differ depending on which herbivore species is feeding, and can attract the specific parasitoid species of that herbivore.

Just as plants are not defenceless against herbivores, insect herbivores defend themselves against their consumers, which are invertebrate insects and spiders, as well as birds, rodents and bats. They do this through physical and chemical defence, camouflage, and mimicry. Any one defence strategy is only effective against some consumers, so most herbivores are defended in multiple ways.

There are many well studied examples of complex direct and indirect interactions between plants, herbivores, and insect predators and parasitoids using model agricultural plants, such as *Brassica* which includes cabbage and rapeseed. There are much fewer studies of wild host plants. This is a significant oversight because it is under natural conditions that the most complex interactions have evolved.





© IISC 2025 – PRIVATE CIRCULATION ONLY

> ***Just as plants are not defenceless against herbivores, insect herbivores defend themselves against their consumers, which are invertebrate insects and spiders, as well as birds, rodents and bats. They do this through physical and chemical defence, camouflage, and mimicry.***

Here at CES, one intriguing plant-animal interaction has been studied in detail – the fig tree and fig wasps. This interaction involves multiple species: specialised mutualistic wasps that only pollinate the flowers that are blooming inside figs, wasps that are parasites of the figs, and wasps that are parasites of the plant-feeding wasps. This set of interactions is extremely specialised. It is also old, having evolved over 50 million years ago.

Currently, researchers at CES are also studying a less specialised insect community associated with the plant family Rutaceae. This family includes cultivated citrus, such as orange and pomelo, as well as curry leaf, and many wild plants that grow in the tropical and subtropical forest understory in India. Because of their chemical defences, Rutaceae mostly host specialised herbivores that feed only on Rutaceae, and in some cases closely related plant families. A good example of this is some of the swallowtail butterflies in the genus *Papilio*. Rutaceae-feeding *Papilio* in India include the common lime *(Papilio demoleus)*, the common mormon *(P. polytes)* and the blue mormon *(P. agenor polymnestor)*. As adults, some *P. polytes* butterflies protect themselves from predation by birds by mimicking butterflies that are chemically defended, though they themselves are not. This is an example of what is called Batesian mimicry.

As caterpillars, all the *Papilio* on Rutaceae are well defended against visual predators, such as birds. This is because they resemble or masquerade as bird droppings when they are small. Then, when they get larger, the same caterpillars resemble snakes, in their colour pattern, as well as their morphology and behaviour, as they can evert a red defensive organ called an osmeterium, which looks and moves like a snake tongue. Despite these extensive defences, the eggs, larvae and pupae of *Papilio* are still vulnerable to both specialist and generalist predators. In our research, we have found that the majority of individual eggs and pupae, and many of the caterpillars, are killed by parasitoid wasps. These parasitoid species include a few known specialists on *Papilio*, an invasive generalist, and many species that have not yet been identified.

The research on figs and fig wasps highlighted here was conducted by Renee Borges and the Syncephalon of her lab. The highlighted work on species associated with Rutaceae is being carried out by Anaswar P, Prakruti Metha and Shreya Gangwal (Saskya van Nouhuys' Lab).

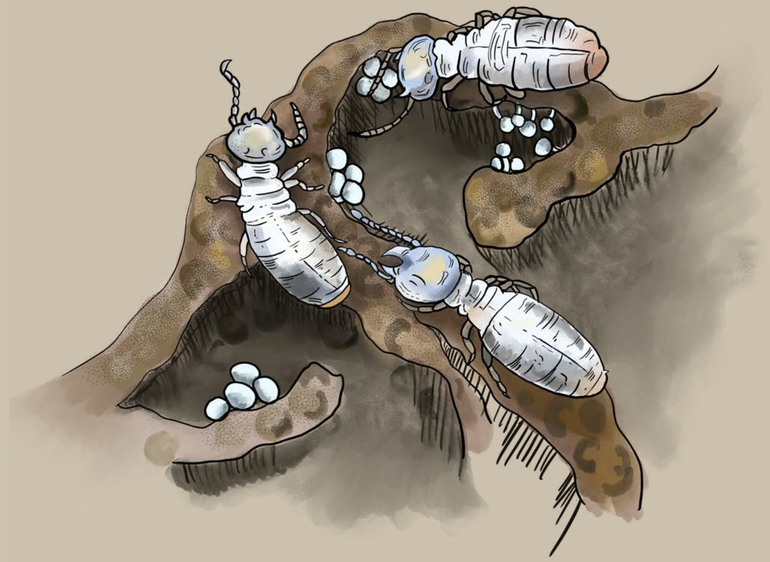


Curious Eyes and Nose of a Natural Historian

Renee M. Borges

© IISC 2025 - PRIVATE CIRCULATION ONLY

For a naturalist, wonder is everywhere. When one sees a young cayman slumbering on a giant Amazon lily leaf, one marvels at how the leaf can support the weight of this ancient reptile. When a Malabar giant squirrel carefully folds a *Memecylon* leaf in a stereotyped behavioural sequence and then bites off only the leaf centre dropping the rest, nothing short of wonder is evoked. The squirrel chews carefully, beginning to feed on the next leaf centre. How does this squirrel know that the outer rims of the leaf are packed with toxins such as alkaloids and should be avoided? Why is this chemical arsenal of the leaf strategically placed at its rims?



Wonder is when an ant alerts other ants about the presence of a caterpillar on the leaf of the ant-plant *Humboldtia* (so-called because it harbours ants in its specially swollen and hollow stems), and the ants collectively either attack and consume the caterpillar or, if it is too big, they cooperate to push it off the leaf. How and why do these *Technormyrmex* ants protect the plant from being attacked by the caterpillar?

Termites of the subfamily Macrotermitinae cultivate a symbiotic fungus inside their nests that breaks down cellulose from wood, making it digestible for them
Ashok Kumar Mallik | Indian Institute of Science Campus, Bangalore



A Crematogaster sp. *ant near a slit on the branch of* Humboldtia brunonis, *which is a domatium made by the plant to house the ants*
Karthikeyan Srinivasan | Agumbe, Karnataka

© IISC 2025 - PRIVATE CIRCULATION ONLY

Wonder is when one sees scores of tiny fig wasps struggling to enter a fig through a tiny opening; the struggle is immense and the wasp wriggles through leaving behind its wings and parts of its antennae. Why would a fig wasp push into a fig with such difficulty and leave its wings behind? Surely, this cannot be the only fig she will visit in her lifetime, for without her wings, how would she reach other figs?

Wonder is when blind termites carry glass beads and cut agar offered in petri dishes to bury alive a parasitic fungus. How does the blind termite recognise the presence of a fungal parasite that can destroy its carefully tended fungal crop? How are fungus-farming termites such efficient weeders? Wonder is a potter wasp taking soil from a termite soil nest and using it to build its own mud pot; the potter wasp carries water in its mouth to wet the soil, and then rolls the soil into a ball which serves as the building blocks of her nest. How does the potter wasp know how much water to mix with the soil?

A special wonder is experienced when the human eye is powerless on a moonless night, but a carpenter bee stirs out of her nest and unerringly finds her food under starlight; the human eye can only witness this phenomenon with the aid of infra-red light. How can this unique nocturnal bee see flower colour under starlight when no other bee can? Why does this bee fly only at night, unlike other bees that are active during the day?

Nature cannot write books herself, and she waits for someone with a curious eye and a nose to tell her stories. Natural history is a much-neglected art, and art it is, because it takes patience, a sixth or seventh sense about the likelihood of a nature story, and a creative means to reel out the story in subtitles for humans to comprehend. This art is somewhat like journalism, when the best reporters pursue a story doggedly until they can hit the front pages with their discoveries. And so, curiosity is an essential ingredient for a story to reveal itself.

“Natural history is a much-neglected art, and art it is, because it takes patience, a sixth or seventh sense about the likelihood of a nature story, and a creative means to reel out the story in subtitles for humans to comprehend.

© IISC 2025 - PRIVATE CIRCULATION ONLY

The philosopher Thomas Nagel in his profound essay *What is it like to be a bat* argues that it is indeed impossible to know what a bat feels, unless one is a bat oneself. But natural historians are not bats. So, we have to pretend that we are bats, or termites, or ants, or squirrels, or an ant-plant, and take on an alter ego every time we make an observation or design an experiment to find out what it is that the bee can see at night, or the termite can smell. It may take years to find the right experiments to decipher without doubt the message that the animal or plant is conveying through its behaviour.

For example, a CES student studied termites that farm fungus for their own consumption. It took the student two years to devise the experiment that told us that fungus-farming termites can recognise by smell just a few bits of the fungal parasite, and that this recognition triggers the live burial of the parasitic fungus and the anointing of anti-fungal compounds on the infection spot. This helped solve a great mystery. Fungus-growing termites have broad-spectrum anti-fungal compounds in their saliva. These anti-fungals could even kill their own fungus crop. The million-dollar question, therefore, was: how do fungus-growing termites prevent the poisoning of their own fungus crops while tending their farms by excluding parasitic fungi? By discovering that termites can sniff out even a few strands of the fungal parasite and take immediate action against this nascent invasion hotspot, the mystery was solved. The termites merely smear the anti-fungal compounds and conduct a live burial of the parasitic fungus at the hotspot; thus, the fungal crop itself is left intact. This is analogous to targeted gene therapy or targeted laser ablation of only selected parts of a tissue so that the rest of the body is left intact.

How does a curious eye and nose of a naturalist develop? A collection of observations without a theme or a hypothesis is a jumble that will make little sense. Ecological and evolutionary theories provide the framework for a natural historian to weave these observations into a meaningful edifice. Testable hypotheses form the glue, and the edifice builds slowly but surely. Nature then begins to speak in a language humans can understand.

The research highlighted here was conducted by Renee Borges and the Syncephalon of her lab.



Female potter wasps (Phimenes flavopictus) *build mud chambers, stocking them with paralysed prey for their offspring*
Jithesh Pai | Doresanipalya Forest Research Station, Bangalore



© IISC 2025 - PRIVATE CIRCULATION ONLY

Bharal, or blue sheep, primarily graze on alpine grasses
Md Abdus Shakur | Spiti, Himachal Pradesh



Wildlife, Ecosystems and Climate

Sumanta Bagchi

Human activities are altering the Earth in unprecedented ways. Rapid changes in the composition of gases in the atmosphere have altered the Earth's climate with direct and indirect impacts on ecosystems. Humans use land for plant production across nearly half of the terrestrial ice-free surface of the Earth and dominate the flows of key elements such as carbon and nitrogen, between land, water, and air. In addition to changes in biological diversity and composition in forests, grasslands, mountains, rivers, lakes, and oceans, human activities have fundamentally altered how ecosystems function.

Ecosystem functions not only regulate processes such as the flow of material and energy through the biosphere but also provide services that we depend on – food, water, fibre, timber, as well as climate regulation. Many ecological functions are directly linked to human livelihoods, while others have deep cultural significance for us. The amounts and reliability of these ecosystem services depends critically on how land (and water) is used. For instance, converting forests or grasslands to farmland not only alters biodiversity but also affects how services can be provisioned by these modified ecosystems. As ecosystem functions get rapidly and thoroughly altered, we face the challenge of obtaining services from landscapes and seascapes in a human-impacted world. For instance, where do we find the water to irrigate farms, or bees to pollinate crops?

Since the dawn of civilisation, starting from the domestication of plants and animals, humans have steadily altered land use across all continents. This has intensified in the modern era with the arrival of industrial farming and animal husbandry. Today, in India, it is common to encounter forested lands being converted for agricultural practices, which in turn can affect the native biodiversity and ecosystem services in these areas. This is as if the world has been carved into two pieces – with and without humans.



© IISC 2025 - PRIVATE CIRCULATION ONLY

Himalayan ibex (Capra sibirica hemalayanus) *ranges often overlap with livestock, leading to competition for forage, especially in winter*
Dhritiman Mukherjee | Spiti, Himachal Pradesh

In this way, the livestock indirectly restricts the potential for carbon sequestration in soil, relative to the wild grazers.



Bharal often graze alongside livestock – such interactions influence carbon and nitrogen cycling
Dhritiman Mukherjee | Spiti, Himachal Pradesh

© IISC 2025 - PRIVATE CIRCULATION ONLY

Research at CES has focused on land use of intermediate intensity, featuring both humans and nature. As such, coupled human-and-natural ecosystems have often survived for millennia, and they offer a glimpse into ways to achieve a more sustainable way of living.

A major focus of research at CES has been on agro-pastoral land use in the Trans-Himalayan ecosystem. Here, humans have farmed the land and raised their livestock in a cold desert environment alongside ibex, bharal, snow leopards and many more fascinating wild animals. Using a long-term field experiment since 2005, we have addressed questions about ecosystem function in the Trans-Himalaya such as primary production and nutrient cycling in the pastoral and natural landscapes. This helps quantify how plants, animals, and microbial decomposers in soil act together to offer important services such as carbon sequestration, and whether land management can offer solutions to current climate change challenges.

The field experiment in the Trans-Himalaya was set up with the help of the people of Kibber village in the Spiti region of Himachal Pradesh. Over the past two decades, this experiment has revealed some interesting aspects of how interactions between plants, animals, and microbes collectively regulate ecosystem level processes such as the cycling of carbon and nitrogen. We find that the vertebrate herbivores provide a valuable ecosystem service in the form of carbon sequestration by modifying the microbial communities and their functions in the soil. Herbivores also modify the plant community composition through diet selectivity, which in turn contributes to greater storage and stability of the soil carbon pools. These grazing herbivores are both wild and domesticated livestock.

Unlike wildlife, some livestock receive antibiotics as part of veterinary care. These antibiotics eventually find their way into the soil, where they affect soil microbes. The microbial community under livestock differs from that under wildlife and shows lower carbon use efficiency. In this way, the livestock indirectly restricts the potential for carbon sequestration in soil, relative to the wild grazers. In addition to soil microbes, the soil-dwelling arthropods also differ between the areas under livestock compared to the wild grazers. While spiders (predators) are suppressed under livestock, grasshoppers (herbivores) and ticks and mites (disease vectors) are abundant. This has implications for grassland degradation as well as for sustainability of this and other coupled human-natural ecosystems (now studied in a One Health Framework).

Overall, this experiment reveals that a well-managed, traditional, pastoral production system is a close approximation of native conditions but falls short in terms of carbon services. Though closely related, livestock are not perfect substitutes for wildlife in terms of ecological functions and services. These functional differences between the two become important targets for sustainable planning under rising demands for livestock products for food security that would further displace wildlife.

The research highlighted here was conducted by Karthik Murthy, Mehreen Khaleel, Shamik Roy, Pronoy Baidya, Dilip Naidu, Mathew Jose and Md. Abdus Shakur (Sumanta Bagchi's Lab).





Evolution



© IISC 2025 - PRIVATE CIRCULATION ONLY

Aboard the Indian Ferry

Praveen Karanth

India harbours incredible biodiversity and is one of only 17 megadiverse countries in the world. Even though India constitutes just 2.5% of the world's area, it has 9% of the world's species of mammals, 12% of birds, 6% of reptiles and 12% of plants. How was this rich biota of India assembled? Was this diversity generated in India or was it derived from elsewhere, and if so, where did it come from? When and how did this happen? These are questions biogeographers attempt to address. Biogeography is a branch of biology that attempts to understand how past geological and climatic events might have contributed to the biodiversity we see today. In the Indian context, we need to journey through India's geological and climatic past to understand its current biodiversity.

When we go back in time to the early days of India's geological history, the world was very different from what it is today. Around 200 million years ago (mya), in the Jurassic period, all the southern continents, including South America, Africa, Madagascar, Australia, Antarctica and the Indian subcontinent were part of the Gondwanan landmass. We know this from fossil records and ancient rock formations in these landmasses. There are numerous examples of similar fauna shared among these landmasses based on fossil data. For example, fossils of the extinct plant *Glossopteris* are found across many of these continents. And similar sauropod dinosaurs – the herbivorous giants with long necks – roamed across these conjoined landmasses. There are rocky outcrops in Madagascar that look strikingly like the ones in peninsular India. In fact, the Western Ghats of India and central highlands of Madagascar bear many similarities, suggesting that these mountains shared the same geological history.

However, things did not remain static; around 120 mya, West Gondwana (Africa and South America) separated from East Gondwana (Madagascar, India and Australia). This was followed by Australia separating from Indo-Madagascar around 90 mya, and India and Madagascar separating from each other around 80 mya. These tectonic events caused the earliest separation of Gondwanan biota. This is known as vicariance, wherein a wide-ranging species gets isolated into multiple populations, in this case on various Gondwanan fragments. Thus, the separation of landmasses resulted in unique but related flora and fauna evolving in these areas.

© IISC 2025 - PRIVATE CIRCULATION ONLY



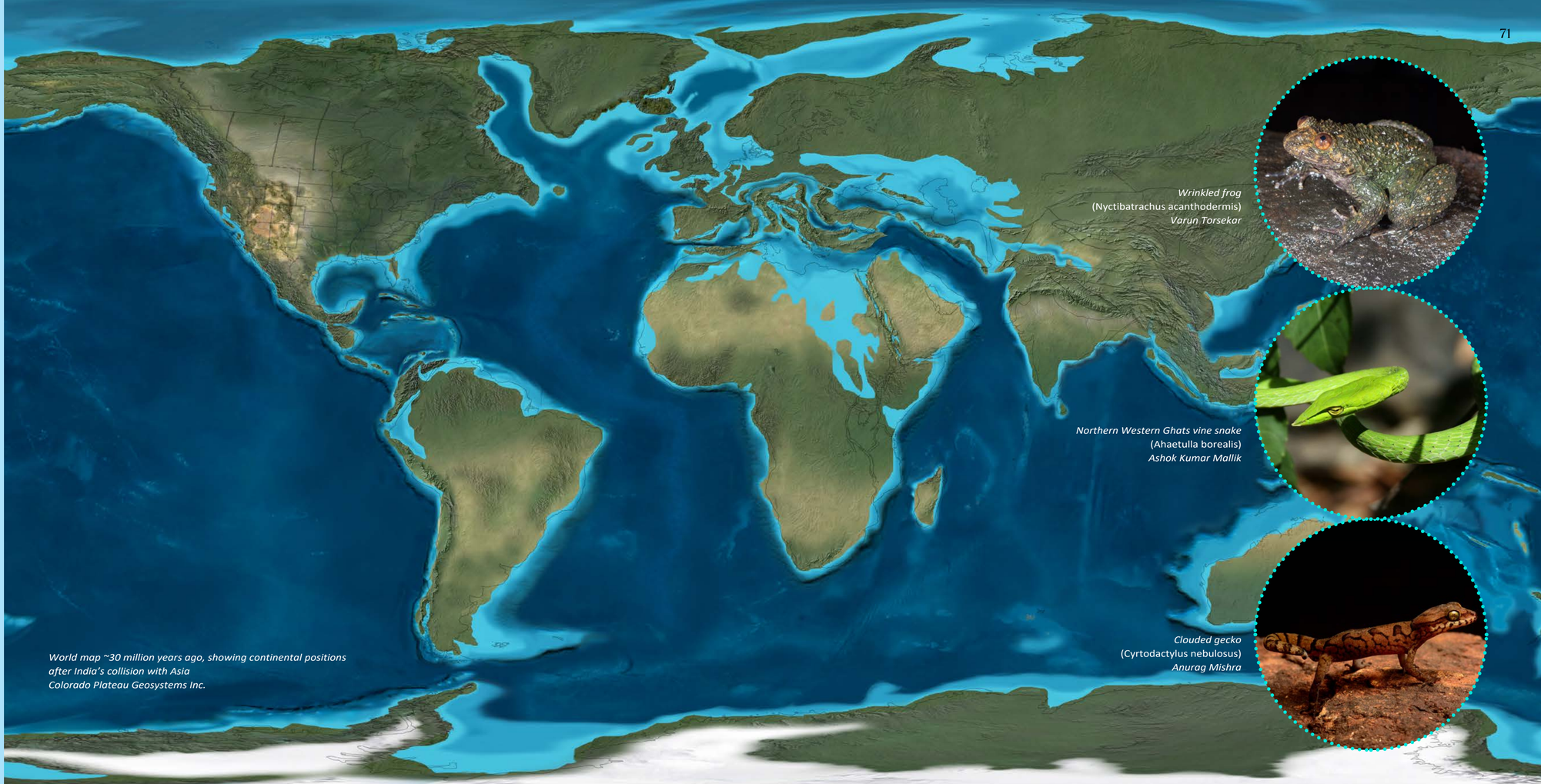
Formed by India's collision with Asia ~50 million years ago, the Himalayas mark the subcontinent's northern boundary and isolate it from the rest of Asia
Kalyan Varma | Ladakh

> ***Upon merging with Eurasia, it is believed that Gondwanan species dispersed out of India into Asia and species already present in Asia dispersed into India.***

After India's separation from Madagascar, the Indian plate travelled from the southern hemisphere to the northern hemisphere and eventually collided with Eurasia around 50 mya. Upon merging with Eurasia, it is believed that Gondwanan species dispersed out of India into Asia and species already present in Asia dispersed into India. Thus, biodiversity in any given area can be generated through vicariance or through the dispersal of a species from one region to another. These scenarios suggest that India harbours ancient Gondwanan biota, which are species that existed in undivided Gondwana as well as immigrants that dispersed from Asia more recently.

As it was drifting towards Eurasia, the Indian plate experienced various events such as the Deccan volcanism, a large volcanic eruption that engulfed much of peninsular India around 66 mya. Around the same time, the globe experienced the fifth mass extinction (which included dinosaurs and much of life as it existed) due to the meteoroid impact in the Gulf of Mexico. After its collision with Asia, India also underwent a dramatic change in climate from warm and humid to more dry cool conditions. It is believed that these events might have wiped out much of the Gondwanan flora and fauna in India. To complicate matters further, the collision of India with Asia resulted in the rise of the Himalayas. The Himalayas form the northern boundary of the subcontinent isolating it from the rest of Asia. What influence did this event have on the dispersal of species from Asia?

© IISC 2025 - PRIVATE CIRCULATION ONLY



World map ~30 million years ago, showing continental positions after India's collision with Asia
Colorado Plateau Geosystems Inc.

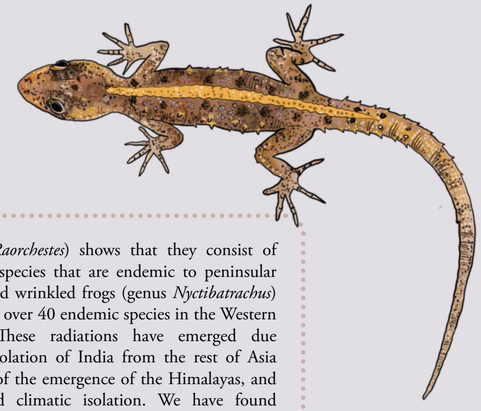
Wrinkled frog
(Nyctibatrachus acanthodermis)
Varun Torsekar

Northern Western Ghats vine snake
(Ahaetulla borealis)
Ashok Kumar Mallik

Clouded gecko
(Cyrtodactylus nebulosus)
Anurag Mishra

© IISC 2025 - PRIVATE CIRCULATION ONLY

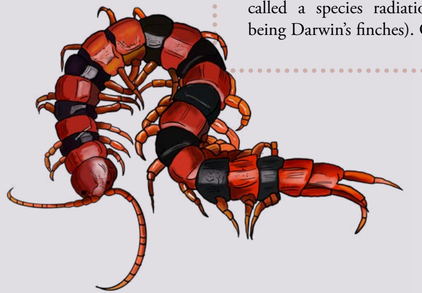
Raorchestes flaviocularis, *an endemic high-elevation species found in the Megamalai Hills*
SP Vijayakumar



To address these questions, modern day biogeographers employ molecular phylogenetic approaches to understand how past events might have shaped the current distributions of taxa. Phylogenetic trees represent the evolutionary relatedness of taxa, based on the similarity of DNA sequences. Species that have similar sequences are genetically closely related and cluster together in the tree. Phylogenetic studies at CES and elsewhere suggest that much of India's land-dwelling vertebrates – including many snakes, lizards and birds – dispersed into India from Asia and there is very little evidence of Gondwanan biota. However, many invertebrates, such as centipedes, appear to be ancient and evolved before the break-up of Gondwana.

Furthermore, many of the vertebrate groups that dispersed into India have undergone rapid speciation within India resulting in what is called a species radiation (a famous example being Darwin's finches). Our work on bush frogs (genus *Raorchestes*) shows that they consist of over 50 species that are endemic to peninsular India, and wrinkled frogs (genus *Nyctibatrachus*) comprise over 40 endemic species in the Western Ghats. These radiations have emerged due to the isolation of India from the rest of Asia because of the emergence of the Himalayas, and associated climatic isolation. We have found that the emerging Himalaya also contributed to diversification in other groups such as gecko lizards of the genus *Cyrtodactylus*. But many groups, such as agamid lizards, vine snakes and pit vipers have both species that evolved in peninsular India and others that dispersed from Southeast Asia. Thus, a complex scenario of vicariance, dispersal and in-situ radiation explains the amazing diversity that we see in India today.

The research highlighted here was conducted by Jahnavi Joshi, Ishan Agarwal, Aniruddha Datta Roy (Praveen Karanth's Lab), S P Vijaykumar and Varun Torsekar (Kartik Shanker's Lab).





© IISC 2025 – PRIVATE CIRCULATION ONLY

Male superb fan-throated lizards (Sarada superba) *flash their dazzling dewlaps, both, to deter rivals and attract females*
Soumabrata Moulick | Pune, Maharashtra

Animals Dress to Impress



Maria Thaker

From the iridescent Himalayan monal and the grand red jungle fowl, to the striking emerald Andaman day gecko and myriad colours of the clown triggerfish, India has amongst the most vibrantly coloured animals in the world. These gorgeous animals are more than just beautiful to us and maybe even themselves, they reflect creative evolutionary solutions to different problems.

Colours and patterns are the most versatile of species traits, playing a vital role in how species interact with their environment and with each other. Evolutionary ecologists study animal colouration to understand its function, and how physical appearance can strongly influence the survival and reproductive success of individuals.

One fascinating function of animal colouration is communication, which is one of the best explanations for the evolution of conspicuous and bright colours. Many animals use colours when communicating with other individuals of their own species, typically to signal their intentions or aspects of their quality. For instance, males of many birds, reptiles, fish, and mammals flaunt bright colouration to signal prowess to potential mates. For this purpose, colours are thought to encode key information about the signaller, which receivers can then evaluate. Put simply, females can use this information to decide whether they are interested in mating with a particular male.

Conspicuous colours have also evolved as warning signals to other species. As warnings, they deter predators by advertising the animal's toxicity. A classic example of warning colouration is the poison dart frog, whose vibrant skin warns predators of its toxic nature. This mechanism, known as aposematism, is a brilliant evolutionary strategy that allows these small animals to survive in a dangerous world.

© IISC 2025 - PRIVATE CIRCULATION ONLY

While bright colours are attractive to the visual systems of animals, including humans, colours and patterns can evolve for the entirely opposite purpose. Camouflage is a survival strategy that allows animals to blend into their surroundings, making them less visible to both predators and prey. Some species, like the leaf-tailed gecko from Madagascar, have evolved intricate patterns that mimic the foliage of their habitat so that predators are less likely to find them. Others, like the venomous reef stonefish of the Indian Ocean blend into the rocks, enabling them to ambush passing prey without being detected.

Any discussion of animal colours would be incomplete if we did not consider the most dynamic expressions of colour in nature. Animals, such as cephalopods (octopus and squid), reptiles and fish, have evolved mechanisms to rapidly change their colours depending on their needs. For example, octopus and squid masterfully shift the colours, patterns, and texture of their skin, depending on whether they are attempting to hide, socially interact with others, or hunt for food. On land, the chameleon is perhaps the most famous example, dynamically changing its skin colour to match its environment. However, this colour changing ability of chameleons is not just about hiding, it is also about temperature regulation and social signalling.

Thus, the evolution of colouration is not a straightforward path; it involves a complex dance between environmental pressures such as thermoregulation, mating requirements, and threat of predation. The interplay of these functions has led to a dazzling display of colours in the animal kingdom. From the flamboyant displays of courtship to the subtle hues of camouflage, colours are crucial for survival, communication, and reproduction.

> ***These gorgeous animals are more than just beautiful to us and maybe even themselves, they reflect creative evolutionary solutions to different problems.***

Lichen huntsman spiders (Pandercetes sp.) *use body patterns and feathery legs to mimic lichen and moss, blending seamlessly into tree trunks*
Jithesh Pai | Agumbe, Karnataka

© IISC 2025 - PRIVATE CIRCULATION ONLY

The strawberry poison dart frog (Oophaga pumilio) *has striking colours to warn predators of its toxicity, derived from a diet of alkaloid-rich ants and mites*
Achyuthan Srikanthan | Costa Rica



Researchers at CES have been studying the evolution and function of vibrant skin, feathers, and scales across the animal kingdom. As a group, frogs are amongst the most visually striking animals – with skin and eyes that are elaborately coloured and mesmerisingly patterned. Our global analysis showed that colours and patterns in frogs seemed to have evolved independently from other key characteristics, such as where the species lives (aquatic or terrestrial), when they are active (nocturnal or diurnal), or even if they care for their young. It turns out that frogs can don a beautiful array of colours while still surviving the challenges of everyday life, including parenthood.

Reptiles in India have evolved both static colours that do not change once the individual has developed, as well as dynamic colours that can change within minutes depending on the context. Males of the superb fan-throated lizard, *Sarada superba*, spend their summers rapidly flapping their large tri-coloured dewlap (extension of skin of the throat). This motion attracts the attention of both sexes, but we have discovered that the blue and black patches on the dewlap draw the attention of other males, while the orange patch attracts females. We suspect that the intensity of blue and black conveys a male's competitive ability while orange is a good indicator of his health. The peninsular rock agama, *Psammophilus dorsalis*, uses the red, orange, yellow, brown and black on its body in even more impressive ways. Males of this species can rapidly change their colour and patterns depending on whether they are courting, competing, stressed, alerted by a predator, broadcasting their territorial position, or thermoregulating. For this species, colour is a nuanced language.



For animals that live in mixed-species groups, colours and patterns become an important part of which species they associate with and whether their associations make them conspicuous or cryptic. We are evaluating these ideas in mixed-species groups of reef fish and birds, to determine whether birds of a feather indeed flock together (or fish of a scale swim together).

The research highlighted here was conducted by Amod Zambre, Anuradha Batabyal, Madhura Amdekar, Seshadri K.S, S. Gangothri (Maria Thaker's Lab) Kanika Aggrawal, Bharat Ahuja (Kartik Shanker's Lab), Aravind Sridharan and Shreekant Deodhar (Kavita Isvaran's Lab).

A License to Kill

Kartik Sunagar

© IISC 2025 - PRIVATE CIRCULATION ONLY

Many animals inject a complex biochemical cocktail called venom into target organisms to facilitate prey capture, for self-defence, during intraspecific competition, or a combination thereof. This cocktail comprises a mixture of proteins, peptides, salts, and other biomolecules that have undergone millions of years of evolution to exert potent effects on the target animal. Venomous animals deliver this poisonous concoction through the infliction of a wound, however tiny it may be. Many employ fangs, pincers, spines and stingers to deliver venom, while some rely on specialised cells. Venom as a trait has independently originated over a hundred times in the animal kingdom, highlighting its adaptive significance. Interestingly, given the high energetic requirements to produce this complex cocktail, venom may have also led to the extinction of many lineages. Since many venomous animals thrive near humans, accidental envenoming of humans and livestock (e.g., through snakebite) is frequent in many regions. As a result, animal venoms are a popular study system for investigation in many fields of biology, including biochemistry, ecology, evolution, and medicine. However, the venomous species of the Indian subcontinent remain largely uninvestigated.



The rhinoceros viper (Bitis nasicornis) *is a vividly patterned snake native to African rainforests, whose horn-like scales and hemotoxic venom make it a formidable predator*
Karthik Sunagar | Kenya



Indian ornamental tarantula
(Poecilotheria regalis)
Dandeli, India



Gaboon viper (Bitis gabonica)
Kenya



Spotted orbweaver (Neoscona sp.)
IISc, Bangalore



Spectacled cobra (Naja naja)
Maharashtra

Bamboo pit viper (Trimeresurus stejnegeri)
Kerala

(all images by) Kartik Sunagar

© IISC 2025 - PRIVATE CIRCULATION ONLY

“The evolution of venom is tightly linked to the ecology of the venomous animal, to the extent that some animals deliver specific combinations of toxins, depending on whether they are hunting for food or defending themselves from predators.

Animal venoms exhibit remarkable structural, functional and compositional variability, which enables them to incapacitate a variety of prey and predators. This variation can have a profound negative impact on human health. For example, snake venoms have been documented to vary extensively between and within species, necessitating the production of different antivenoms tailored to specific snake species or even populations. Since India suffers the brunt of snakebites with the highest annual rates of human mortality (58,000) and morbidity (100,000+) globally, venom research in the country has primarily focussed on select species of clinically relevant snakes with a broad geographic distribution. Geographic variation in the venoms of Russell’s viper *(Daboia russelii)*, one of the world’s clinically most relevant snake species, was demonstrated as early as 1988. Researchers at the University of Mysore sourced *D. russelii* venoms from three locations across India, and by using a technique called column chromatography, documented subtle differences in the venom composition across regions. Several studies have been conducted since then on the so-called ‘big four’ Indian snakes (spectacled cobra, common krait, Russell’s viper and saw-scaled viper). Most studies, however, have sourced venoms from captive populations and/or from select locations, limiting our understanding of the true extent of venom variation and its impact on snakebite therapy.

© IISC 2025 - PRIVATE CIRCULATION ONLY

Snake venoms have been mainly studied from a pharmacological and biochemical perspective, and the relevance of understanding the ecology and evolution of venoms for developing effective snakebite treatments has been realised in recent years. By undertaking a country-wide collection of venom from wild-caught snakes across India's diverse biogeographic regions, research at CES has uncovered the remarkable venom variation in the clinically most relevant Indian snakes, and its alarming repercussions on the effectiveness of antivenoms. These research findings accentuate the significant role of the biotic and abiotic factors in shaping the composition and potency of snake venoms. Research at CES has not only uncovered venom variation within species across different regions but has also unravelled extensive compositional and functional variation between individuals at a single locale. The venom of individuals has also been documented to vary across development stages (e.g., between neonate, juvenile and adult stages) to facilitate changes in diet with age.

Snakebites have been historically treated with antivenoms, which are produced by injecting horses with low doses of target snake venoms and harvesting antibodies from these immunised horses for use in humans, a strategy that has remained virtually unchanged for over a century. This strategy necessitates the production of specific antivenoms for distinct snake populations/species. In recent years, researchers have attempted to address the severe shortcomings by harnessing advanced immunological techniques and producing what are known as recombinant antivenoms. Since they have mostly focussed on non-Indian snake species, these studies do not address the snakebite scenario in India – the global hotspot for snakebites. Research at CES addresses this by producing recombinant antibodies effective against the venoms of medically important snakes worldwide, including those found in India. One such antibody of human origin was able to neutralise the venoms of snakes from India, Southeast Asia and sub-Saharan Africa, highlighting the possibility of producing 'universal antivenoms'. Other solutions for snakebites, including the utility of orally administrable drugs and chemical compounds of plant origin, are also being explored in CES.

The evolution of venom is tightly linked to the ecology of the venomous animal, to the extent that some animals deliver specific combinations of toxins, depending on whether they are hunting for food or defending themselves from predators. The influence of these factors on the venomous animals and their venoms in the Indian subcontinent remains completely uninvestigated. Research at CES is filling this knowledge gap by exploring the role of biotic and abiotic factors in driving the evolution of venom in a plethora of species, including ants, bees, centipedes, fish, lamprey, scorpions, spiders and wasps. In particular, the role of diet, environment, sociality, division of labour, predator pressure, genetics, phylogenetic histories and delivery mechanisms (e.g., fangs versus stingers) in shaping animal venoms is being investigated. Toxins discovered from the venoms of such largely overlooked animal groups are being studied to develop effective medications and environmentally friendly bioinsecticides.

Overall, these investigations have underscored the importance of understanding venom ecology and evolution in advancing our knowledge of the biology of these enigmatic animals, as well as in designing effective therapeutics.

The research highlighted here was conducted by Senji Laxmi, Arpan Samanta, Yashika, Rashmi, Rudresha GV, Muralidhar Nayak, Prasad Gond, Ajinkya Unawane, Siddharth Bhatia, Naeem Sheikh, Suyog Khochare, Salil Javed and Mihir Kumar (Kartik Sunagar's Lab).

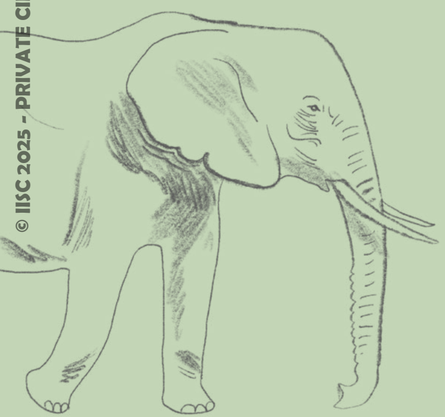


Russell's viper (Daboia russelii)*, one of India's 'Big Four' snakes, causes up to half of the country's venomous snakebites*
Kartik Sunagar | Kerala

The Elephant in a Nutshell

Raman Sukumar

© IISC 2025 - PRIVATE CIRCULATION ONLY



The evolutionary history of elephant-like creatures goes back about 60 million years before present to the ancient Tethys Sea. A bewildering array of proboscideans roamed the globe since then, until most of them eventually became extinct, leaving behind only *Elephas maximus* (the present-day Asian elephant), *Loxodonta africana* and *L. cyclotis* (the African savanna and forest elephants, respectively). Climate change since the Mid-Miocene epoch, about 14 million years before present, has shaped the feeding preferences and evolutionary changes of 'elephants' in South Asia. These animals shifted from a browsing diet of foliage, bark and fruit from trees and shrubs to a diet dominated by grass, about 7 million years ago. Surprisingly, *E. hysudricus*, the ancestor of *E. maximus* began to include substantial amounts of browse, a legacy continued by the modern species. This could be due to competition from both its relative, the gigantic grazer *Palaeoloxodon namadicus*, as well as from humans who occupied the river valleys and grasslands, thereby pushing the elephant into the hills and dense rainforest where browsing became almost obligatory. It is no wonder that a creature evolutionarily equipped to feed on grass avidly seeks out the lush fields of paddy and millet crops that humans cultivate!

The outcome of this long evolutionary history, shaped by climate and vegetation change, has meant that a megaherbivore such as the elephant has to consume large quantities of plant material. They pick well over 100 species of plants in the southern Indian dry forests and consume 8-10% of their body weight in fresh forage each day. Although elephants eat a lot of grass, especially during the rainy months, the analysis of stable carbon isotopes in collagen protein extracted from the bones of dead animals has shown that 70% of carbon came from browse plants. Elephants also raid cultivated crops primarily for their superior nutritive qualities, with males willing to take far greater risks in venturing into agricultural fields as they could potentially gain more through successful expression of musth and reproductive opportunities.



> ***Elephants also raid cultivated crops primarily for their superior nutritive qualities, with the males willing to take far greater risks in venturing into agricultural fields.***

Kalyan Varma | Valparai, Tamil Nadu



© IISC 2025 - PRIVATE CIRCULATION ONLY

Large tuskers have become increasingly rare due to a history of poaching for ivory
Kalyan Varma | Nagarahole National Park, Karnataka

Beyond being the largest living land animals, elephants are well known for their intelligence and social behaviour. They live in complex societies comprising female-led families with varying levels of social bonding based on kinship. Older females, or matriarchs, are generally believed to play a particularly important role during their annual movements in search of food or water. In India, the annual home ranges of elephant herds can be 250-1000 square kilometres. Adult bulls typically join the family groups only for mating. Male elephants too maintain loose ties among members of 'bachelor groups' which come in very handy when they venture into agricultural fields.

Smell and sound play major roles in elephant communication. The extra-long nose of the elephant confers phenomenal abilities of smell, enabling them to recognise companions, potential mates and detect danger in the environment. In addition to the sounds we can hear, they use low frequency rumbles (below human hearing limits) which can travel kilometres through vegetation to communicate with each other for social contact and mating.

In this journey through the world of elephants, I have invariably been drawn into several other aspects such as conservation of the species, for which the nature of its relationship with humans is critical. One of my most enjoyable pursuits was to document the deep cultural history of the elephant-human relationship. I delved into ancient texts and wandered across the continents in search of monuments, temples and museums with elephant motifs and artifacts. The sacred elephant of Buddhism and Hinduism was clearly related to the utility of the captive animal in the emergence of Asian civilisations and its large-scale deployment in warfare – a role which then transformed into that of a draught animal for the logging industry. Clearly, the historical relationships between elephants and people have to be understood as we plan for the conservation of the species, of which only about 50,000 remain in the wild and 15,000 in captivity.



Many herds may coalesce into larger groups, especially during the dry season, when water is scarce
Kalyan Varma | Nagarahole National Park, Karnataka



Elephants live in complex social groups, led by females and often guided by matriarchs
Kalyan Varma | Nagarahole National Park, Karnataka

© IISC 2025 - PRIVATE CIRCULATION ONLY

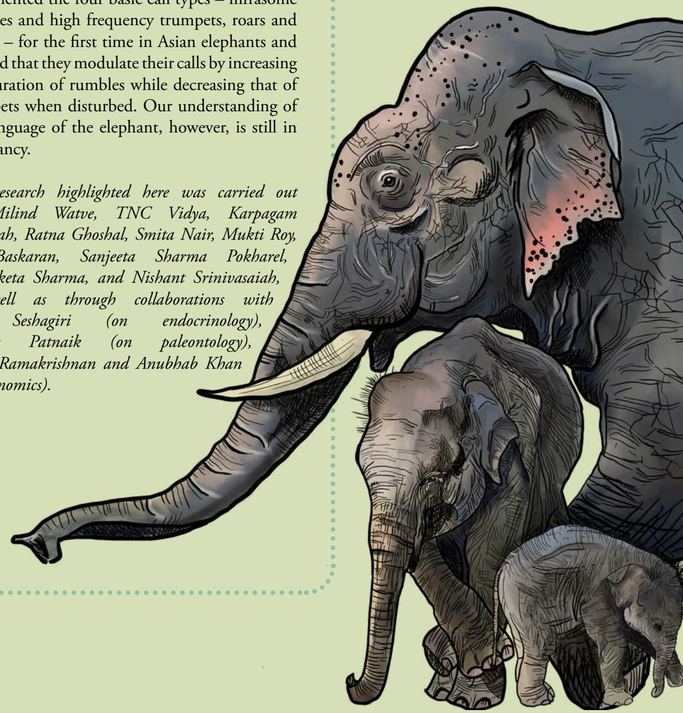
We have worked across India and other Asian countries on elephant ecology, evolution, behaviour, physiology and genetics. Our work on Asian elephant evolution documented two matrilines or clades with evolutionary histories driven by the cycles of the ice ages. Our recent analysis of whole genomes of elephants across India for the first time revealed how elephants evolved in the north of India with subsets of populations sequentially colonizing the south with reduced genetic variation.

We documented the fluid nature of the all-male bachelor groups and how the group sizes increased with greater availability of cultivated crops. We also found that elephants living outside protected forests on a predominant diet of cultivated crops were indeed in better body condition with lower levels of glucocorticoids than those residing inside.

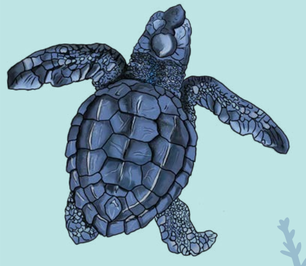
Both musth and tusks have been hypothesised to give male elephants an advantage in reproduction. Our work in the Western Ghats showed that tusks in male elephants were most likely signals to females of their superior resistance to parasites and diseases. In contrast, musth (and not possession of tusks) was the primary determinant of dominance among males and of choice by females for mates in Kaziranga.

The discovery of 'infrasonic' communication in 1986 sent a ripple of excitement through the community of elephant researchers. We documented the four basic call types – infrasonic rumbles and high frequency trumpets, roars and chirps – for the first time in Asian elephants and showed that they modulate their calls by increasing the duration of rumbles while decreasing that of trumpets when disturbed. Our understanding of the language of the elephant, however, is still in its infancy.

The research highlighted here was carried out by Milind Watve, TNC Vidya, Karpagam Chelliah, Ratna Ghoshal, Smita Nair, Mukti Roy, N. Baskaran, Sanjeeta Sharma Pokharel, Nachiketa Sharma, and Nishant Srinivasaiah, as well as through collaborations with PB Seshagiri (on endocrinology), Rajeev Patnaik (on paleontology), Uma Ramakrishnan and Anubhab Khan (on genomics).



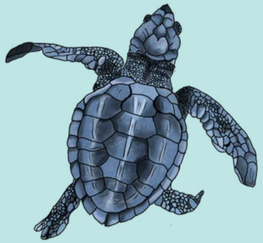
© IISC 2025 - PRIVATE CIRCULATION ONLY

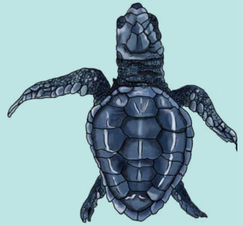






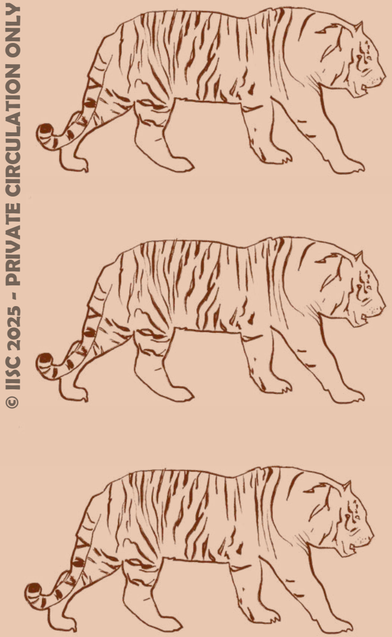
Conservation





The DNA of Rarity

Anubhab Khan



There is a massive rise in the number of species that are endangered and may face extinction soon. Some of the major drivers of this ongoing mass extinction event, known as the Anthropocene, are habitat loss and modifications, fragmentation of populations, poaching, illegal trade, pollution and many other factors driven by humans, which have led to the decline of population sizes and isolation of populations. It is a huge challenge to conserve species and protect them from anthropogenic impacts. There are measures being undertaken from many directions, with genetics being one of the important approaches to species conservation.

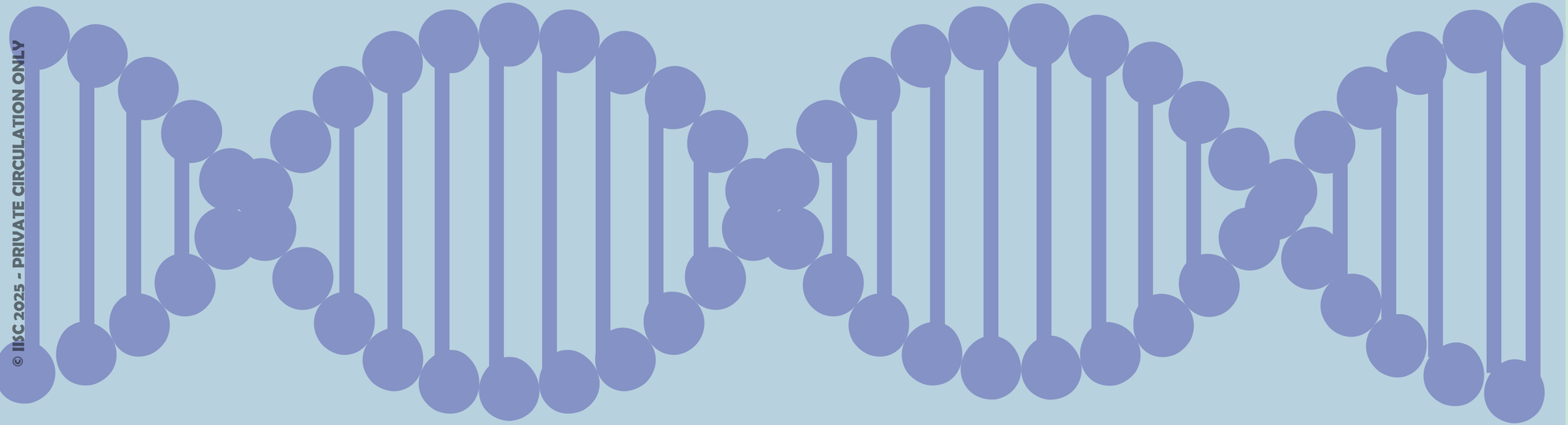
Genetics is the study of inheritance of traits. Traits of an organism are coded into their DNA sequences, collectively known as the genome. Attributes of the genome are influenced by the number of ancestors of an individual, isolation or migration of ancestors, the number of mutations and selection pressures; all collectively known as evolutionary forces. The evolutionary forces leave a signature on the genome which can be used to conserve and manage wild populations.

Some of the most routine examples of conservation genetics involve delineating species, identifying populations that need to be managed differently, assessing threats to a population and estimating history of a populations. Additionally, there are many important aspects of conservation where genetics is used as a tool, such as for census of populations, curbing wildlife trafficking, choosing pairs for mating in captivity, and choosing individuals for translocations.

A fundamental aspect of the field of population genetics is estimating the number of distinct populations of a species. Let's take one of the most endangered species, tigers. Tigers are found in about 11 countries across Asia. There have been debates about the number of units (subspecies) the global population can be divided into. In 2015, a study suggested there should be only two distinct subspecies of tigers, one in the Sunda Islands and the other in continental Asia; the continental tigers further being subdivided into Amur tigers and the rest.

© IISC 2025 - PRIVATE CIRCULATION ONLY

Extensive studies have led to tiger conservation over an area of approximately 85,000 sq.km but other species need genetic data to inform conservation measures
Kalyan Varma | Kanha National Park, Madhya Pradesh



© IISC 2025 - PRIVATE CIRCULATION ONLY

However, genetic studies found evidence that suggests there are at least five populations of extant tigers that split from each other about 10,000 years ago, and each of them should be managed separately. This would involve breeding individuals from different subspecies separately in zoos, making conservation plans specific to each subspecies, restricting rewilding and translocation projects based on the subspecies found in different areas, allocating separate resources for each of the subspecies, and many more considerations.

India has over 60% of the global tiger population and all tigers here belong to the Bengal tiger subspecies. Within India, it is estimated that there are at least four independent units of tigers that split from each other 7000 to 2000 years ago. Recently, there were reports of tigers being sighted on the island of Java in Indonesia, and with very limited data it was suggested that it is the extinct Javanese tiger. However, upon further investigation it was determined that a tiger might have been sighted on the island of Java, but whether it was a member of the extinct Javanese tiger lineage needs proper genetic analysis, which could not be performed due to lack of infrastructure.

© IISC 2025 - PRIVATE CIRCULATION ONLY

The conservation genetics literature is ripe with studies conducted in the global north, which is species poor, while the species in the biodiversity rich tropics are understudied. An example of this bias might be the dolphins and whales, together referred to as cetaceans. The genomes of cetacean species in the global north have been well studied, and their conservation action plans have been influenced by these genetic studies. Several fundamental insights about the various adaptations in these species are extremely well known.

Although there are 31 species of dolphins and whales across the Indian coast, there is hardly any literature on the genetics of Indian cetaceans. We do not know, for example, the number of individuals in some of these species, the changes in their population size through time, the basis of unique adaptations like surviving under low oxygen, visibility and sleep. A lack of conservation genetic information leaves the future of Indian cetaceans in peril.

The situation is even more dire for species endemic to the Indian subcontinent, such as the Gangetic and Indus river dolphins, Kolar leaf-nosed bats, Bugun liocichla and many more. Here in CES we actively work towards bridging this gap. We are studying the genetics of our native species in the wild using the latest technologies and are developing capacity to train the next generation of scientists and conservationists to protect this heritage.

The research highlighted here was carried out by Anubhab Khan and his collaborators.



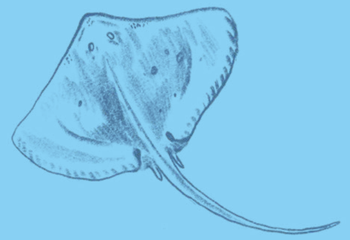
The evolutionary forces leave a signature on the genome which can be used to conserve and manage wild populations.

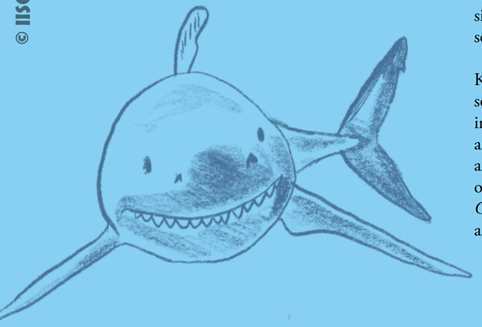
The Ganges river dolphin is one of the few freshwater dolphins in the world, and a close relative of the Indus river dolphin
Dhritiman Mukherjee | West Bengal, India

Icons of the Ocean



Kartik Shanker





Throughout history, humans have been obsessed with large, and sometimes dangerous animals, hunting big game either for meat or to signal strength and courage. Whether as a product of need or primate curiosity, an interest in natural history blossomed in peoples around the world. By the 20th century, we were forced to transition into the conservation of declining populations of these species. Most of these charismatic animals are vertebrates, and largely mammals. Symbols of conservation around the world use these animals to evoke awe and make our hearts bleed. The giant panda, found in small pockets in China, is ubiquitous as WWF's logo. The same goes for the elephant, tiger, lion or rhino. These animals are used as 'flagships' of conservation by focussing attention, funding and effort for the terrestrial habitats and ecosystems they inhabit. Along similar lines, many animals in the sea have also served as marine flagships.

Known for their advanced intelligence, complex social groups and vocal communication, including the ability to 'talk' to humans, whales and dolphins (cetaceans) have captured the hearts and minds of people worldwide. In fact, the title of the fourth book of Douglas Adams' *Hitchhikers Guide* series, *So long and thanks for all the fish*, is a message from the dolphins who had long been aware of Earth's pending destruction, before they leave for an alternate dimension. *Moby Dick* is another symbol of our fascination with whales, but also a recognition of centuries of exploitation of cetaceans that led to severe declines in many species. In recent decades, the International Whaling Commission's moratorium on commercial whaling has reduced this impact, but Aboriginal whaling is allowed in certain places, and some countries do not recognise the ban.

Sea turtles have perhaps the widest following, with conservation groups in over 100 countries worldwide. Several aspects of their biology have rendered them susceptible to threats and, at the same time, suitable as flagships for conservation. Since they come ashore to nest, they become instantly accessible to researchers, conservationists and the public. And yet, the fact that they disappear into the sea as hatchlings, and then only ever return as adults to the same beaches where they were born, shrouds their lives with a certain mystery that tickles our imaginations. With their complex lifecycle, where males and females migrate thousands of kilometres from feeding to breeding grounds, and their navigation using the Earth's magnetic field to their natal beaches, sea turtles are instant gratification for scientist and citizen alike.

© IISC 2025 - PRIVATE CIRCULATION ONLY



Common dolphins are found in coastal and offshore waters across the world
Dhritiman Mukherjee | Costa Rica



The unique head shape of great hammerhead sharks gives them a wide field of vision and helps pin prey like stingrays to the sea floor
Dhritiman Mukherjee | The Bahamas

© IISC 2025 - PRIVATE CIRCULATION ONLY

The seven species of sea turtles are just a little bit different from each other. For example, green turtles are herbivorous, feeding on seagrass; hawksbills are amazingly spongivorous, chomping through silica; and leatherbacks feed exclusively on jellyfish to become the largest of sea turtles, weighing over 600 kg. Most remain largely in tropical waters, but the leatherback forays into temperate and sub-arctic waters in search of food, even regulating its temperature in defiance of the convention that reptiles are 'cold-blooded'. All of this fuels the narrative that a wide range of ocean habitats need to be protected to enable their survival.

In recent years, sharks and rays have also become a focus of marine conservation. Like sea turtles and cetaceans, and unlike fish, they are slow-growing and mostly produce a few live young. Contrary to sea turtles and cetaceans, sharks in particular have been portrayed largely as fearsome killers, made famous by movies like *Jaws*. But their deep evolutionary history, originating over 400 million years ago (making them nearly twice as old as mammals and reptiles), and their remarkable diversity with over 1000 species, has brought them into the limelight of conservation as well.

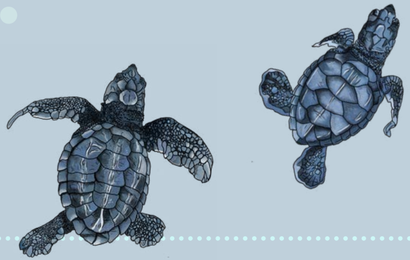
Though all these groups were once widely hunted, fished, consumed and traded, much of the threat today comes from incidental catch in fishing and degradation of habitat due to coastal development and shipping, and climate change. For sea turtles, where sex is determined by the temperature that eggs experience during incubation, a warming climate means that predominantly females will be produced, which can affect the survival of populations.

> ***These animals are used as 'flagships' of conservation by focussing attention, funding and effort for the terrestrial habitats and ecosystems they inhabit.***



Olive ridley turtles arrive at Rushikulya during the February 2025 arribada, when about 500,000 turtles nested within a week
Bipro Behera | Rushikulya, Odisha

© IISC 2025 – PRIVATE CIRCULATION ONLY



Since most marine flagships are long-lived and late maturing, many years of data are required to detect changes to their populations. We have been setting up long-term monitoring programmes for these species across India to track population trends and other aspects of their biology. For nearly two decades, CES has, in collaboration with Dakshin Foundation, monitored sea turtles at important sites across the coast.

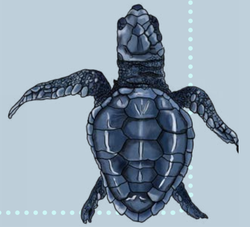
We monitor leatherback turtles on Little Andaman Island, where the population has been stable or increasing. Satellite telemetry of these turtles reveal their remarkable journeys, with some migrating several thousand kilometres eastwards to Australia and East Timor. Others migrated over 10,000 kilometres to the west, reaching the coasts of Madagascar and Mozambique.

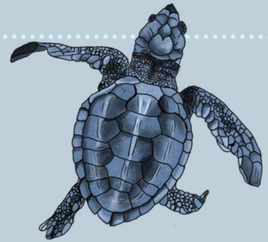
Olive ridleys show the extraordinary phenomenon of 'arribadas' or mass nesting, an extravaganza of egg-laying where thousands of female turtles come ashore simultaneously to nest. Odisha hosts two of the biggest mass nesting rookeries globally. Given concerns about the possible decline in this population due to mortality in trawl fisheries, we started monitoring them at Rushikulya in the early 2000s. Since then, arribadas here have increased in size from >50,000 nests to nearly a million nests in 2025, suggesting that they are doing well in the short term. The project also monitors offshore mating aggregations, hatching success and hatchling sex ratios across years.

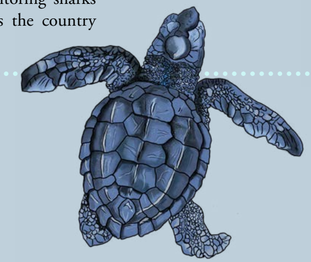
We also monitor foraging population of green turtles in the lagoons of the Lakshadweep Islands. As they demolish the seagrass meadows in one lagoon, they move to others in search of food, leading to a cycle of seagrass decline and recovery, and changes in green turtle abundance across years at these lagoons.

In addition, we have started monitoring sharks and rays at landing centres across the country including catch composition, but also genetics, diet, microplastic and heavy metal contamination in these species. Such monitoring helps us track the health of species and ecosystems and provides guidance for conservation and management.

The long-term research highlighted above was led by M. Muralidharan, Chandana Pusapati, Adhith Swaminathan, Nupur Kale, R. Hariprasath, Garima Bora, Vidisha Kulkarni, Ema Fatima, Chetan Rao, Trisha Gupta, Shawn Dsouza and includes many other researchers (Kartik Shanker's Lab and Dakshin Foundation).







The Insidiousness of Invasion

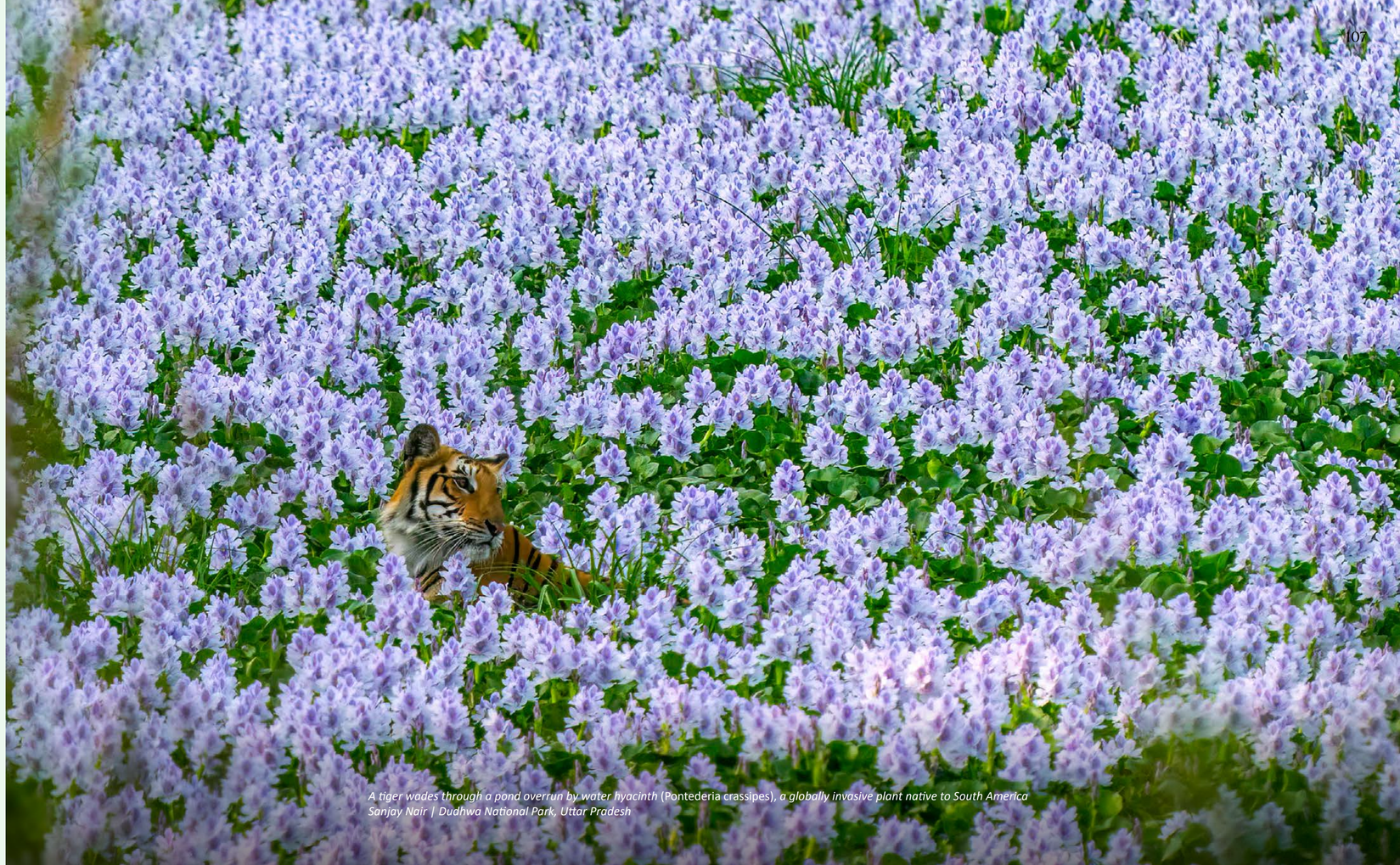
Saskya van Nouhuys

The Earth is inhabited by species living together in communities. The plants, animals, fungi and other organisms in these communities have evolved over hundreds of millions of years, while interacting with one another, and in response to local environmental conditions. Over time, communities change due to speciation and extinction, and also dispersal, which leads to species range shifts. These changes are driven on a long timescale by evolution, geological processes, and periodic natural shifts in the climate.

One of the many ways in which humans have affected the Earth over the last few thousand years is by facilitating the movement and establishment of species between geographically distant places. This can transform resident communities. A good part of the movement of species around the globe has been intentional, such as the many species of plants and animals that European colonists carried and nurtured in new places. But many other organisms are transported unintentionally through the movement of goods between ports and overland. Of course, some introductions have little or no consequences for native flora and fauna. For instance, ornamental roses most likely originated from wild roses in China and have been brought nearly everywhere, but on their own, they do not spread in the landscape. Agricultural crops and livestock have been spread over the world, and through our farming practices have had a profound impact on landscapes. Consider for example, the transformation of 16 million hectares of tropical forests in Indonesia to palm oil plantations. But still, most agricultural species are cultivated and do not spread on their own.

And then there are species that arrive in a new location, establish a population and spread, all while displacing other species. These are called invasive. The chances of a handful of newly arrived individuals achieving this is miniscule. However, ports, roadways, railways and airplanes assure a continual source of propagules of potential invasive species, some of which establish. These propagules can be anything alive: seeds or plant parts, insects, mammals, birds, reptiles, fish, parasites, or pathogens. The human-mediated movement of organisms has led to the global homogenisation of many ecological communities, with a decline of biodiversity and a risk to many endemic species.

© IISC 2025 - PRIVATE CIRCULATION ONLY



A tiger wades through a pond overrun by water hyacinth (Pontederia crassipes), *a globally invasive plant native to South America*
Sanjay Nair | Dudhwa National Park, Uttar Pradesh



© IJSC 2025 - PRIVATE CIRCULATION ONLY

The red-eared slider turtle (Trachemys scripta) *is native to North America but invasive worldwide*
Manjunath Olekar | Bangalore, Karnataka

Ecologists and evolutionary biologists ask two important questions about the process of species invasion. One is, what makes a species able to invade a new habitat? The second is, what makes a habitat vulnerable to invasion? The answer to the first question is two-fold. First, the species must be transported to the new location alive. A species that has a hearty life stage, such as an impermeable seed, has an advantage. Species that are abundant at their source and inhabit landscapes that humans do are also more likely to get transported to new places. For instance, the invasive weed *Parthenium hysterophorus* originated in tropical America and has moved around the globe in grain and livestock feed. The potential invader also must have a competitive advantage over existing species at their new location. Some species are inherently competitive due to their evolutionary history, or they may have an advantage in a new habitat as a result of arriving without the consumers or competitors that kept the population in check where it originated.

The second question, about what makes a community invadable, also has several answers. A vulnerable community is in environmental conditions that are suitable to the invasive species. This explains why there are many invasive plants from South America in Peninsular India, which has similar climates and habitats. Second, and importantly, is the amount of disturbance in the new environment. When an environment is disturbed, the species composition of the existing community is affected, which can free up resources for new invasive species to use. Natural disturbances, such as seasonal flooding, natural fire, and disease have increased in frequency due to humans. We have also increased disturbance through urbanisation, expanding agriculture, and climate change. Alteration of the environment through disturbance may add resources that are more accessible to invaders than to native species. Such is the case in some grasslands, which become dominated by invasive plants due to increased nitrogen from fertilisers and industrial pollution. Disturbance can also decrease resource availability to existing species, allowing invasive species that are adapted to low resources to flourish. For example, groundwater depletion, the building of dams or the channeling of water for human use causes a decline of native species and an increase in drought-tolerant invasive species. Changes such as these, and many others, facilitate invasive species by creating opportunities for species adapted to the new conditions.

Many invasive species occur in India, including invasive plants that pose significant threats to native biodiversity and ecosystems. *Ageratum conyzoides,* in the family Asteraceae, commonly known as billygoat weed, is among the top ten most invasive plants in India. Native to Central and South America, it was likely introduced to India accidentally through contaminated agricultural seeds. It spreads rapidly due to its small, lightweight seeds, which facilitate easy dispersal in disturbed areas such as roadsides and open-canopy forests. Despite its invasive nature, the plant has ethnobotanical significance with traditional use as a remedy for treating wounds in Northeast India. Balancing its ecological impact with its cultural roles is a challenge for conservationists.

© IISC 2025 - PRIVATE CIRCULATION ONLY

Some species are inherently competitive due to their evolutionary history, or they may have an advantage in a new habitat as a result of arriving without the consumers or competitors that kept the population in check where it originated.

Researchers at CES are studying restoration of native vegetation in the lower elevations of Eaglenest Wildlife Sanctuary, Arunachal Pradesh, where *A. conyzoides* dominates most of the abandoned patches of forest land. The plant blooms throughout the year, but during its peak flowering season, from November to February, fields covered in its purple flowers resemble a natural Valley of Flowers. These showy blooms attract major pollinators, disrupting native plant-pollinator networks. As in Arunachal Pradesh, the proliferation of invasive plant species is disrupting natural communities across India, and indeed, the world. Finding ways in which to restore native vegetation in invasive-dominated habitats and limiting the further spread of invasive species is crucial to recovering the structure and function of natural communities, along with the myriad interactions between species that characterise them.

The research highlighted here was conducted by Anisha Mandal (Umesh Srinivasan's Lab).



The common myna (Acridotheres tristis) *is native to South Asia but invasive worldwide*
Evan Chiu (CC0) | New Taipei, Taiwan

It's Getting Hot Out There

Maria Thaker

We have all noticed the changes in weather patterns over the last few years. Hotter summers, shifts in monsoon timings, unexpected floods, and uncontrolled fires are becoming more frequent and intense. It is also abundantly clear to scientists around the world why these weather patterns are shifting – climate change. The rapid rise in global temperatures, driven largely by human activities, is profoundly affecting ecosystems and the variety of life they support. As the climate continues to change, organisms are responding in various ways, showcasing both resilience and vulnerability.

Two of most noticeable responses of plants and animals to warmer temperatures have been changes in when and where they do certain activities. Phenological changes, which are changes in the timing of critical life events, have become very clear over the last 40 years. Many plants are flowering and fruiting earlier in the season, numerous bird species are shifting their migration timing, leaving their breeding grounds earlier in the spring and arriving at wintering grounds later, and several frog species in the northern hemisphere are breeding earlier. While these shifts in timing are an effective response to changes in environmental temperatures, they can lead to phenological mismatches across interacting species. If pollinators do not correspondingly shift their timing of emergence or activity in ways that match the timing of flowers, or if insects hatch sooner than the arrival of birds that feed on them, the phenological mismatch between mutualists or predators and their prey can be devastating.

Another way that organisms are responding to increasing global temperatures is by shifting their space use or distribution to higher elevations or latitudes as climate zones shift. In some mountainous regions of the world, alpine tree species are shifting their distribution to higher elevations where it is still cooler. Many fish species, such as the Atlantic mackerel and European hake, have moved northward into cooler waters. Butterflies in Europe have also shifted their ranges northward into new areas that have lower temperatures. As with the shifts in phenology, shifts in spatial distribution can lead to spatial mismatches between species that once comprised an interacting community.

© IISC 2025 - PRIVATE CIRCULATION ONLY



Corals bleach when warming seas disrupt their symbiotic relationship with algae, often leading to their death
Dhritiman Mukherjee | Andaman and Nicobar Islands

India, with its diverse ecosystems, is showing signs of climate change impacts. As temperatures rise, so too have the number of research studies that are rapidly assessing how this global phenomenon is affecting the flora and fauna of India. In Kashmir, the blooming of the lovely yellow flowers of the gur toor *(Sternbergia vernalis)* is tightly linked to temperature. Over the last four decades, these flowers that mark the onset of spring, have been blooming earlier. Coral reefs around the Lakshadweep Islands, Andaman and Nicobar Islands, and along the coasts near Goa have been experiencing more frequent and extensive bleaching events over the last 15 years. Coral bleaching is directly linked to increasing water temperatures that disrupt the symbiotic relationship between coral and zooxanthellae, which are the small algal mutualists that live in coral tissue. Although corals can recover from bleaching events, this recovery will be difficult if sea temperatures continue to rise. In the Himalayan region, temperatures are rising at twice the rate of most parts of the northern hemisphere. As a consequence of warming and human activities in the area, the distribution of the large and charismatic carnivores that live there, the common leopard, snow leopard, and Asiatic black bear, have contracted since the early 1990s. Snow leopards seem to be shifting their home ranges to higher elevations, away from human settlements and towards areas where permanent glaciers are still present. The common leopard and Asiatic black bear on the other hand have been forced to lower elevations, closer to human settlements where there is more vegetation. The climate change-induced shifts in the distribution of these carnivores and of other large mammals across India are expected to increase human-wildlife conflict if we do not plan mitigation strategies in anticipation.

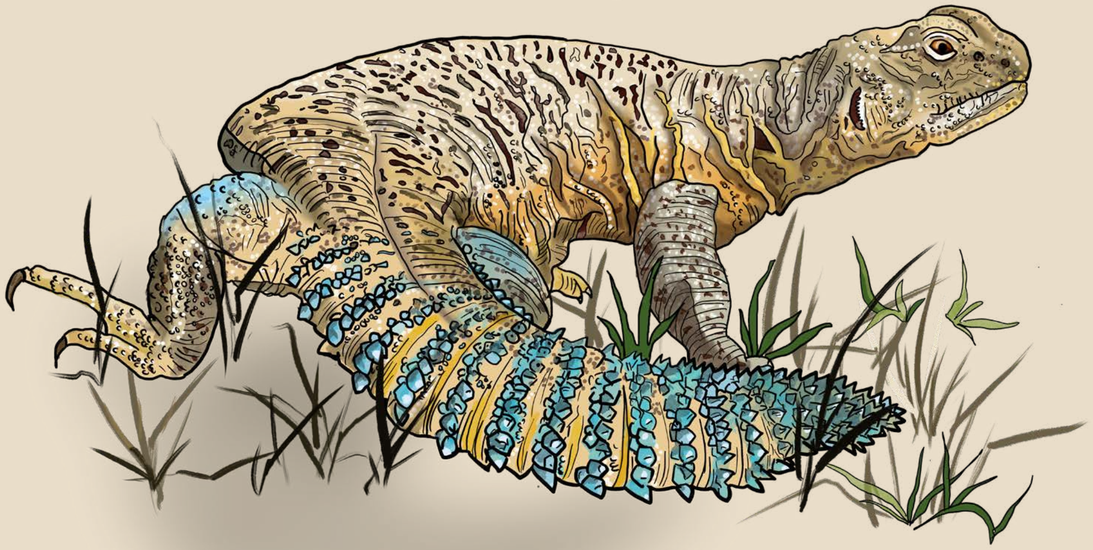
> ***The scientific understanding of which types of species will adapt and in what ways will have to outpace the rate of temperature increase for us to go beyond being a bystander to actually preserving biodiversity and ecosystem functionality.***

© IISC 2025 - PRIVATE CIRCULATION ONLY



As the Himalayas warm at nearly twice the global rate, snow leopards are being pushed higher into glacier-fed ranges
Dhritiman Mukherjee | Spiti, Himachal Pradesh

© IISC 2025 - PRIVATE CIRCULATION ONLY



The spiny-tailed lizard (Saara hardwickii) *survives extreme heat by taking refuge in its burrow*

Researchers at CES have been studying the impact of climate change on Indian biodiversity in a range of ways. One way is to study taxa at one of the most extreme and vulnerable places in India – the Thar desert, where organisms are already experiencing temperatures ranging from over 50°C in the summer days to 3°C in winter nights. The Thar desert is home to some of the most temperature-resilient taxa, which include drought-tolerant sewan grass *(Lasiurus sindicus Henr)* and the herbivorous spiny-tailed lizard *(Saara hardwickii)*. By combining field observations of the activity of spiny-tailed lizards and laboratory experiments on their thermal physiology, we learned some critical information of current thermal tolerance capabilities and adaptation strategies of this lizard.

While their physiological responses and behavioural strategies are effective today, projections of warming conditions indicate that by 2099, sprint speed and foraging activity will decrease significantly, and lizards may be restricted to their burrows for too many hours in the day to fulfil their survival needs. We have replicated this study in a range of other taxa, including agamas, geckos and frogs in Southern India, where semi-arid habitat conditions are likely to worsen. Understanding their thermal adaptation strategies is essential.

Studies like these bear witness to the consequences of climate change on organisms and their ecosystems. It is important to remember that plants and animals have evolved a suite of morphological, physiological, and behavioural strategies that enable them to tolerate changes in their environment. The scientific understanding of which types of species will adapt and in what ways will have to outpace the rate of temperature increase for us to go beyond being a bystander to actually preserving biodiversity and ecosystem functionality.

The research highlighted here was conducted by Avichal Tatu, Mihir Joshi, Seshadri KS, Pushkar Wagh, Saumitra Dhere, Vaishnavi Apte and Amanda Ben (Maria Thaker's Lab).

© IISC 2025 - PRIVATE CIRCULATION ONLY

Biodiversity in the Age of Humans

Umesh Srinivasan



Between about 50,000 and 12,000 years ago, the early global migrations of human beings *(Homo sapiens)* rapidly expanded both the geographical range and the ecological footprint of humanity. This 'overnight' colonisation of most of Earth's surface by humans – a veritable blitzkrieg by the standards of geological time – resulted in arguably what was the first extensive extinction event driven largely by humans, primarily because of hunting (the 'overkill' hypothesis). This Quaternary (or Pleistocene) extinction wiped out a large fraction of mammalian megafauna (large mammals weighing ~100 kg or more), including giant sloths, woolly mammoths and saber-toothed cats in the Americas, cave lions and cave bears in Europe, marsupial lions and giant kangaroos in Australia, and hippopotamuses and giant pangolins in Asia.

This major extinction event permanently altered the composition of mammalian fauna, which subsequently came to be dominated by smaller species. In the rainforests of the Amazon, for instance, the South American tapir (~250 kg) is the largest surviving mammal, far, far smaller than the giants of the Pleistocene – Megatherium, an extinct South American ground sloth that weighed up to four tons. The disappearance of these very large 'keystone' animals had profound global ecosystem-level impacts because these species regulated vegetation structure and ecosystem function through herbivory and predation. For instance, it is thought that, in some parts of the world, the loss of mega-herbivores led to a shift from open habitats like grasslands to denser forest.



A rusty-fronted barwing (Actinodura egertoni) *ringed with a numbered aluminium ring and colour rings, enabling research on behaviour and population dynamics*
Aman Biswakarma | Eaglenest Wildlife Sanctuary, Arunachal Pradesh

© IISC 2025 - PRIVATE CIRCULATION ONLY



The dodo (Raphus cucullatus), *a large flightless bird native to Mauritius, went extinct within 80 years of its discovery – an iconic case of human-driven extinction*
Photograph of a museum reconstruction of the dodo by Thilo Parg (CC BY-SA 3.0)

> ***So massive is this ongoing human-induced disruption to natural systems that experts have declared the present biodiversity crisis as the sixth ever mass extinction... the 'Anthropocene,' or the age of humans.***

Following these megafaunal extinctions, the pace of species loss appears to have declined in the relatively climatically stable Holocene (the current geological age) – except on islands. On islands, species often evolved in the absence of predators, losing anti-predatory adaptations. Some birds, for example, lost flight, and attained massive sizes compared to their mainland counterparts, a phenomenon known as island gigantism. As humans colonised islands, they exploited these species on an unprecedented scale, including the elephant birds on Madagascar, the moas in New Zealand and most infamously, the dodo on Mauritius. Humans also carried with them to these islands rats, pigs and other species that preyed on nests and outcompeted native species.

Especially since the beginning of the Industrial Revolution (in about 1780), Earth has entered a new and accelerated age of extinction. According to estimates, the planet is currently losing biodiversity at between 100 to 1,000 times more than the 'baseline' extinction rate, the rate at which species were naturally lost since the appearance of life on Earth. So massive is this ongoing human-induced disruption to natural systems that experts have declared the present biodiversity crisis as the sixth ever mass extinction in the history of life on Earth (like the fifth one 66 million years ago that wiped out the dinosaurs), and have suggested that the geological age that we live in be called the 'Anthropocene,' or the age of humans. And the pace of this crisis is accelerating – since 1970, for instance, wild vertebrate populations across the world have crashed by 70%. Today, humans and their livestock account for 96% of mammal biomass on Earth; only 4% is represented by wild mammals, from mice to elephants.

Anthropocene biodiversity loss is caused by what are known as 'global change drivers.' These include uncontrollable climate change arising from the burning of fossil fuels and the resulting increase in atmospheric carbon dioxide concentrations. Climate change is radically re-arranging life on Earth in space and time, causing species to shift their geographical ranges to cooler regions and changing the timings of important events in species' life cycles such as migration and breeding. Additionally, the loss and fragmentation of natural habitats is reducing living space for wild species and isolating wild populations in more-and-more disconnected 'islands' of degraded habitat in a sea of human-dominated landscapes. Concomitant with these threats are the spread of invasive species and new diseases, the rampant over-harvesting of wild populations (e.g., in fisheries) and the pollution of land, sea and air.

© IISC 2025 - PRIVATE CIRCULATION ONLY



Mid-elevation wet temperate forests (~1800 to 2600 MASL) in the Eastern Himalaya are dominated by oaks, maples, birches, chestnuts and alders
Tarun Menon | Arunachal Pradesh, India

Several research groups at CES study Anthropocene impacts on biodiversity across marine and terrestrial habitats using both theoretical approaches and lab- and field-based data collection. These studies involve species from lizards to birds to mammals, insects and plants.

From the high Himalayas and arid ecosystems to the Western Ghats and oceanic islands, CES researches how carbon is stored and cycled in natural and disturbed ecosystems, how the survival of wild populations of forest birds and coral reefs is impacted by climate change and habitat degradation, and how global change drivers might change key aspects of animal behaviour and physiology, and plant community composition. An important area of research is understanding how small populations of rare and endangered species might fare in a warmer, more disturbed world. In the lab, experiments are uncovering how temperature stress affects the physiology and behaviour of animals in natural and human-modified habitats. Researchers at CES also use theoretical models to predict, for instance, how entire ecosystems might 'tip' from natural to alternative states.

One of CES's field-based projects is in the Eastern Himalaya of Arunachal Pradesh, where a long-term study is tracking how hundreds of bird species are responding to the joint impacts of climate change and forest degradation. It is by now well-established that primary (or, undegraded) forest still remains our first-line defence against biodiversity loss in the age of climate change. Today, however, not only are global temperatures generally rising everywhere, but locally degraded forest patches are much hotter and drier than primary forest that support much less of the most important food for most Eastern Himalayan birds: caterpillars, other insect larvae and spiders. The choice now facing many of these bird species is Darwinian: adapt or die. Over the past 15 years, for example, the annual survival rates of some bird species such as the white-gorgeted flycatcher have plummeted in degraded forest (from about 80% in 2011 to 40% in 2025) but have remained stable in primary forest.

The message is clear; the future of biodiversity – and of humanity indeed – is dependent on safeguarding what little is left of relatively intact habitats. To investigate these vital processes, CES hosts the Long-Term Ecological Observatories programme of the Ministry of Environment, Forest and Climate Change, monitoring populations and ecosystems across the length and breadth of the country, the first such initiative of its kind in India.

The research highlighted here was conducted by Sumanta Bagchi's Lab, Vishwesha Guttal's Lab, Kartik Shanker's Lab, and Maria Thaker's Lab. The research on bird population dynamics was carried out by Kanika Aggarwal, Ritobroto Chanda and Akshay Bharadwaj (Umesh Srinivasan's Lab) in collaboration with researchers from multiple institutions.



© IISc 2025 | PRIVATE CIRCULATION ONLY

CES was started in 1983. The giant liana (Entada pursaetha) *became a unique and distinguishing feature of the department's first home*
Natasha Mhatre | Indian Institute of Science Campus, Bangalore

Acknowledgements

The Centre for Ecological Sciences owes a great debt of gratitude to the Ministry of Environment, Forest and Climate Change, which provided funding for its first building and supported it annually for nearly three decades. CES has also received support from the Department of Biotechnology–Indian Institute of Science Partnership Programme, and the faculty have received support from many Indian and international organisations over the years.

The work of CES could not have been carried out without permission from and the support of numerous Forest Departments around the country. In particular, we would like to thank the Forest Departments of Andaman and Nicobar Islands, Andhra Pradesh, Arunachal Pradesh, Assam, Goa, Gujarat, Himachal Pradesh, Jharkhand, Karnataka, Kerala, Lakshadweep Islands, Madhya Pradesh, Maharashtra, Odisha, Rajasthan, Tamil Nadu, Uttarakhand and West Bengal. In many states, CES has conducted long-term research over two or more decades, which simply would not have been possible without the support of Forest Departments, both from the PCCF's office and from local officers and staff.

The vast majority of the research represented in this book was carried out by our PhD students, MSc students, interns, researchers and postdoctoral fellows (here and there, faculty have even carried out some research all by themselves). CES researchers have been a force to reckon with, producing high-quality science while being fun and creative, and bringing an abundance of joy to the department.

The department is run quietly in the background by its administrative and housekeeping staff, some of whom have served in the office for decades. Equally important, the support staff in the labs have ensured that the faculty and students can get on with their work, minimally troubled by paperwork and other hurdles.

Last but not by far the least, little of CES's work would be possible without the legions of local staff at our various field sites. Bringing deep understanding of the landscapes and their flora and fauna, these naturalists have contributed traditional ecological knowledge, organised local logistics, ensured safety, provided nourishing food, and brought priceless camaraderie and humour to our work in the field. From charging elephants and precarious paths to *dunghi* rides in stormy seas, we have endured and explored with them by our side.



© IISC 2025 - PRIVATE CIRCULATION ONLY

Authors



Anubhab Khan studies the survival of small populations and the evolution of complex traits. He is broadly interested in understanding the role of diversity in survival of populations across biological timescales and the genetic underpinnings that explain biodiversity. He is also actively involved in capacity building activities to encourage wildlife genetic studies across the tropics.



Umesh Srinivasan studies the joint impacts of climate change and forest degradation on bird population dynamics and community composition. Most of his work is field-based and in the montane forests of Arunachal Pradesh. He also partners with tribal communities and the forest department on conservation initiatives to protect endangered species.



Kartik Sunagar is an evolutionary biologist who investigates venomous animals and their venoms to address fundamental questions in ecology, evolution and genetics. His research aims to uncover the drivers of venom variation to design efficacious snakebite treatment and improve health outcomes for rural communities in the developing world.



Sumanta Bagchi works on ecological functions and services in coupled human-and-natural ecosystems. He is particularly interested in the ecology of carbon and the role of plants, herbivores, and microbes in the global carbon cycle and how they influence the earth's climate system.



Maria Thaker works on understanding how morphology, physiology, and behaviour integrate in animals, such as reptiles, amphibians, and mammal mesocarnivores. She is particularly interested in understanding whether and in what ways animals adapt to human-induced challenges, such as urbanisation and climate change.



Vishwesha Guttal explores how stochasticity influences collective behaviour and ecological tipping points. Using theory, data, and data-driven models, he investigates how local interactions and noise drive schooling and cooperation, and how ecosystems transition between states. His work integrates statistical physics with ecology to reveal dynamics in finite, complex systems.



Kavita Isvaran is a behavioural ecologist who loves watching animals and puzzling out what leads to the diversity that we see in behaviour and life histories. She studies how complex ecological conditions in the wild shape animal phenotypes. She is also interested in using behavioural ecological approaches to address applied problems.



Kartik Shanker works on macroecology and evolutionary biogeography in both terrestrial and marine ecosystems, the behaviour of birds and reef fish, and on marine flagship species such as sea turtles, sharks, and rays. He has written several books on sea turtle conservation in India and a few children's stories.



Praveen Karanth focuses on the application of phylogenetic tools in understanding micro- and macro-evolutionary processes. He is particularly interested in biogeography, character evolution, molecular systematics and conservation genetics.



Saskya van Nouhuys studies how interactions among species influence their populations and communities. Before joining CES, she investigated mechanisms of (meta)population dynamics of parasitoid wasps and their butterfly hosts in Europe, and the biological control of insect pests. Now she also studies insect communities on Rutaceae (Citrus) and grassland plant communities.



Rohini Balakrishnan is a bioacoustician and behavioural ecologist who studies animal acoustic communication at the interface of sensory, behavioural and community ecology. She examines how multiple selection pressures, as well as ecological and evolutionary constraints, affect signal structures, communication and decision-making in animals.



Renee Borges is a behavioural and chemical ecologist who studies inter-species interactions, especially in the contexts of mutualism and parasitism between plants, insects, nematodes and fungi. She also studies the engineering properties and design of animal-built structures such as termite mud mounds and potter wasp nests.



Raman Sukumar has worked for decades on the ecology, evolution and behaviour of Asian elephants, particularly in the context of human-wildlife conflict. His long-term forest plot in the Nilgiris, monitored since the 1980s, has provided key insights into tropical forest dynamics. He has also studied paleo-climate and serves as Vice Chair on the IPCC bureau.



Raghavendra Gadagkar has established an active school of research in animal behaviour, ecology and evolution. The origin and evolution of cooperation in animals, especially in social insects is a major goal of his research. Utilizing crucial elements in India's biodiversity, he has added a special Indian flavour to his research.



Rusty-fronted barwing,
Actinodura egertoni



Paper wasps,
Ropalidia marginata



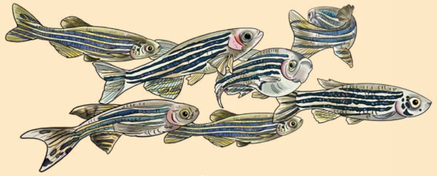
Indian Tiger Centipede,
Scolopendra hardwickei



Lesser false vampire bat,
Megaderma spasma

© IISC 2022 – PRIVATE CIRCULATION ONLY

Illustrations by Ravi Jambhekar



Zebrafish, *Danio rerio*



Common lime butterfly pupa, *Papilio demoleus,* and a parasitoid wasp, *Pteromalus puparum*



Domesticated and wild Rutaceae



Macrotermitinae termites and their symbiotic fungus





Peninsular rock agama,
Psammophilus dorsalis



Asian elephant,
Elephas maximus





Lantana,
Lantana camara



Spiny-tailed lizard,
Saara hardwickii

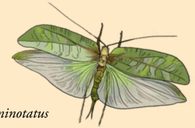




Bush frogs,
Genus Raorchestes



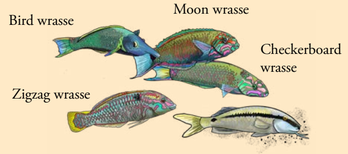
Mysore day gecko,
Cnemaspis mysoriensis



Bush cricket,
Onomarchus uninotatus



Asian Forest Scorpion,
Heterometrus spinifer



Bird wrasse
Moon wrasse
Checkerboard wrasse
Zigzag wrasse
Dash-and-dot goatfish



Crocodile-bark tree,
Terminalia crenulata



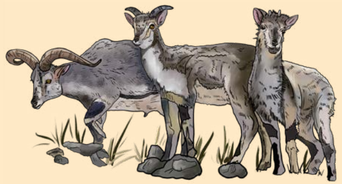
Changpa goat,
Capra aegagrus hircus



Billygoat-weed,
Ageratum conyzoides



Olive ridley turtle hatchling,
Lepidochelys olivacea



Bharal, *Pseudois nayaur*



Ganges river dolphin,
Platanista gangetica



© IISC 2025 - PRIVATE CIRCULATION ONLY

A shola-grassland montane ecosystem in the the higher elevations of the Nilgiri Mountains in the southern Western Ghats; the photograph was taken in the pre-DSLR era on Fujichrome slide film, circa 1995
Kartik Shanker | Mukurthi National Park, Tamil Nadu

© IISC 2025 - PRIVATE CIRCULATION ONLY



There is grandeur in this view of life, with its several powers, having been originally breathed into a few forms or into one; and that, whilst this planet has gone cycling on according to the fixed law of gravity, from so simple a beginning endless forms most beautiful and most wonderful have been, and are being, evolved.

Charles Darwin
On the Origin of Species, 1859

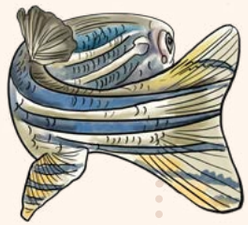
One's ideas must be as broad as Nature if they are to interpret Nature.

Sherlock Holmes, *A Study in Scarlet*
Arthur Conan Doyle, 1887

IISc Press

CES Centre for Ecological Sciences Indian Institute of Science

© IISC 2025 - PRIVATE CIRCULATION ONLY

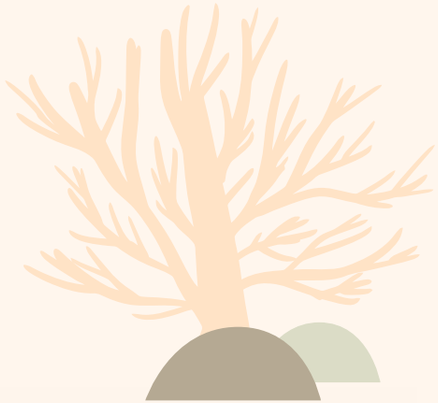


The Centre for Ecological Sciences was founded in 1983 with the support of the Ministry of Environment, Forest and Climate Change, India. Over the past 42 years, CES has instilled a tradition of rigorous enquiry in diverse areas of ecology, evolution and behaviour. Many of the projects are integrative and use multiple approaches, from theoretical and laboratory studies to field-based research. A number of research areas are breaking new ground in ecology, while others have significant roles in conservation.

CES's teaching programme has expanded and diversified over the past 20 years, and our student and postdoc strength is at an all-time high. CES has also been involved in several outreach programmes, including organising workshops for students from marginalised groups, specialised training programmes in advanced areas of ecology and evolution, and capacity building for the Forest Department across India. CES faculty and staff work with local communities at field sites throughout the country, and provide inputs into government policies. It is in such initiatives, by a generation trained in the rigour of science but steeped in the spirit of collegiality and collaboration, that we see a great future for ecology and evolution in India.

In the coming decades, we expect that CES will continue to evolve, expand and diversify its activities in teaching, research, outreach and conservation, while maintaining its high standards of academic excellence.











IISc Press

CES
Centre for Ecological Sciences
Indian Institute of Science